XVII A.P.
DÜSSELDORF
21.5-1.6 1990
CCIR

XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990

INTERNATIONAL TELECOMMUNICATION UNION

RECOMMENDATIONS OF THE CCIR, 1990

(ALSO RESOLUTIONS AND OPINIONS)

VOLUME VI

PROPAGATION IN IONIZED MEDIA

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

CCIR

1. The International Radio Consultative Committee (CCIR) is the permanent organ of the International Telecommunication Union responsible under the International Telecommunication Convention "... to study technical and operating questions relating specifically to radiocommunications without limit of frequency range, and to issue recommendations on them..." (International Telecommunication Convention, Nairobi 1982, First Part, Chapter I, Art. 11, No. 83).*

2. The objectives of the CCIR are in particular:

a) to provide the technical bases for use by administrative radio conferences and radiocommunication services for efficient utilization of the radio-frequency spectrum and the geostationary-satellite orbit, bearing in mind the needs of the various radio services;

b) to recommend performance standards for radio systems and technical arrangements which assure their effective and compatible interworking in international telecommunications;

c) to collect, exchange, analyze and disseminate technical information resulting from studies by the CCIR, and other information available, for the development, planning and operation of radio systems, including any necessary special measures required to facilitate the use of such information in developing countries.

* *See also the Constitution of the ITU, Nice, 1989, Chapter 1, Art. 11, No. 84.*

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92-61-04221-X

Geneva, 1990

PLAN OF VOLUMES I TO XV
XVIIth PLENARY ASSEMBLY OF THE CCIR

(Düsseldorf, 1990)

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All references within the texts to CCIR Recommendations, Reports, Resolutions, Opinions, Decisions and Questions refer to the 1990 edition, unless otherwise noted; i.e., only the basic number is shown.

Printed in Switzerland

DISTRIBUTION OF TEXTS OF THE XVIIth PLENARY ASSEMBLY OF THE CCIR IN VOLUMES I TO XV

Volumes and Annexes I to XV, XVIIth Plenary Assembly, contain all the valid texts of the CCIR and succeed those of the XVIth Plenary Assembly, Dubrovnik, 1986.

1. Recommendations, Resolutions, Opinions are given in Volumes I-XIV and Reports, Decisions in the Annexes to Volumes I-XII.

1.1 *Numbering of texts*

When a Recommendation, Report, Resolution or Opinion is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. Within the text of Recommendations, Reports, Resolutions, Opinions and Decisions, however, reference is made only to the basic number (for example Recommendation 253). Such a reference should be interpreted as a reference to the latest version of the text, unless otherwise indicated.

The tables which follow show only the original numbering of the current texts, without any indication of successive modifications that may have occurred. For further information about this numbering scheme, please refer to Volume XIV.

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* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3 *Reports (cont.)*

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* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3.1 *Note concerning Reports*

The individual footnote "Adopted unanimously" has been dropped from each Report. Reports in Annexes to Volumes have been adopted unanimously except in cases where reservations have been made which will appear as individual footnotes.

1.4 *Resolutions*

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2. **Questions** (Vols. XV-1, XV-2, XV-3, XV-4)

2.1 *Numbering of texts*

Questions are numbered in a different series for each Study Group: where applicable a dash and a figure added after the number of the Question indicate successive modifications. The number of a Question is completed by an *Arabic figure indicating the relevant Study Group.* For example:

- Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;
- Question 1-1/10 would indicate a Question of Study Group 10, whose text has been once modified from the original; Question 1-2/10 would be a Question of Study Group 10, whose text has had two successive modifications.

Note – The numbers of the Questions of Study Groups 7, 9 and 12 start from 101. In the case of Study Groups 7 and 9, this was caused by the need to merge the Questions of former Study Groups 2 and 7 and Study Groups 3 and 9, respectively. In the case of Study Group 12, the renumbering was due to the requirement to transfer Questions from other Study Groups.

2.2 *Assignment of Questions*

In the plan shown on page II, the relevant Volume XV in which Questions of each Study Group can be found is indicated. A summary table of all Questions, with their titles, former and new numbers is to be found in Volume XIV.

2.3 *References to Questions*

As detailed in Resolution 109, the Plenary Assembly approved the Questions and assigned them to the Study Groups for consideration. The Plenary Assembly also decided to discontinue Study Programmes. Resolution 109 therefore identifies those Study Programmes which were approved for conversion into new Questions or for amalgamation with existing Questions. It should be noted that references to Questions and Study Programmes contained in the texts of Recommendations and Reports of Volumes I to XIII are still those which were in force during the study period 1986-1990.

Where appropriate, the Questions give references to the former Study Programmes or Questions from which they have been derived. New numbers have been given to those Questions which have been derived from Study Programmes or transferred to a different Study Group.

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VOLUME VI

PROPAGATION IN IONIZED MEDIAS

(Study Group 6)

TABLE OF CONTENTS

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STUDY GROUP 6

PROPAGATION IN IONIZED MEDIA

Terms of reference

To study with the object of improving radiocommunication:

1. the propagation of radio waves through the ionosphere, and through ionized regions beyond the ionosphere;

2. the characteristics of related radio noise.

1986-1990	*Chairman:*	L. W. BARCLAY (United Kingdom)
	Vice-Chairmen:	G. L. MUTTI (Zambia (Republic of)) Miss G. PILLET (France)

As from the next Study Period, in conformity with Resolution 61 adopted at the XVIIth Plenary Assembly, Düsseldorf (May-June 1990), the scope of the work which will be undertaken and the names of the Chairman and Vice-Chairmen are as follows.

STUDY GROUP 6

RADIO WAVE PROPAGATION IN IONIZED MEDIA

Scope:

Propagation of radio waves, in ionized media, at and above the surface of the Earth and the characteristics of radio noise for the purpose of improving radiocommunication systems.

1990-1994	*Chairman:*	L. W. BARCLAY (United Kingdom)
	Vice-Chairmen:	Miss G. PILLET (France) D. G. COLE (Australia) A. GIRALDEZ (Argentina) M. ZAMANIAN (Iran (Islamic Republic of))

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 6

1. General

During the Plenary cycle just concluding, Study Group 6 has continued with its task of providing up-to-date and relevant information concerning propagation in ionized media, and radio noise. The emphasis continues to be on the provision of documentation for system planning, operation and design.

2. Organization

During the study period, the Working Group structure has been maintained unchanged from the previous cycle. This structure has provided, over a period of 12 years, a framework for the development of Recommendations and Reports in readily identifiable topic areas which have been reflected in the section headings within Volume VI (Dubrovnik, 1986). There has been a considerable imbalance in the workload in the Working Groups due to the priorities for study within administrations and agencies, but this has been accommodated without difficulty by the provision of a suitable distribution of meeting time.

The Study Group has been extremely fortunate in having the same team of Working Group Chairmen at both the Interim and Final Meetings. These were:

- Miss G. Pillet, Vice-Chairman, France – Editorial Group;
- Dr. C. M. Rush, United States of America – Working Group 6-J – Ionospheric characteristics and propagation;
- Dr. D. G. Cole, Australia – Working Group 6-K – Operational considerations;
- Dr. Th. Damboldt, Federal Republic of Germany – Working Group 6-L – Factors affecting system design;
- Dr. M. Zamanian, Islamic Republic of Iran – Working Group 6-M – Natural and man-made radio noise;
- Mr. I. E. Davey, United Kingdom – Working Group 6-N – Field strengths above 1.6 MHz.
- Mr. D. Ross, Canada – Working Group 6-P – Field strengths below 1.6 MHz.

The work of the Study Group, both during the meetings and throughout the whole study period, has been most effective and efficient, aided by the CCIR Secretariat, notably Dr. K.A. Hughes.

3. Conference preparations

3.1 *WARC HFBC-87*

At the time of the 1986 Plenary Assembly, Recommendation 621 was approved which provided improvements to the numerical constants and the interpolation procedure used in the WARC HFBC propagation prediction method. This Recommendation was taken into account at the 1987 WARC. It has now served its purpose and is proposed for deletion. At the 1987 Conference, the CCIR was invited to undertake studies of the HF propagation prediction method adopted by the Conference and to recommend both improvements in the method and later, if necessary, an improved method to be used in the future for the HF bands allocated exclusively to the broadcasting service.

The data banks of HF field-strength measurements compiled by Study Group 6 were extensively used in the development and testing of the method which forms the basis of that used by the Conference. There is thus little scope for the study and testing of improvements to the method, unless further data become available. This was recognized by WARC HFBC-87 which also recommended that administrations should conduct HF field-strength measurement programmes and should contribute data in a form suitable for study to the CCIR.

Consequently Study Group 6 took urgent action in May, 1987 to create Interim Working Party 6/14 with the following terms of reference:

- to determine the areas of the world, path lengths and frequencies for which field-strength measurements should be made in order to establish a new measurement data base which may be used in studying improvements to the HF propagation prediction method;
- to recommend transmission characteristics and antennas and appropriate means for identification of transmissions;
- to recommend receiver systems including antennas to be used when making measurements, together with methods for the recording and analysis of results including standardized forms in which data may be contributed to the data base;
- the work should be completed prior to the Interim Meeting of the Study Group in 1988.

The IWP, under the able chairmanship of Dr. Damboldt (Federal Republic of Germany) prepared Report 1149 which was approved by the Study Group at its Interim Meeting. The Report proposes a set of nine transmitting stations in different parts of the world each radiating a special modulation format for unambiguous transmitter identification both aurally and by computer, and each radiating sequentially on five frequencies. Taking account of the special nature of the transmitting signals, a modestly priced receiving installation was specified whereby one receiver with computer control and data storage would be able to collect field-strength measurements data on 25 transmitter/frequency combinations.

The content of this Report was notified to administrations in August, 1988 and special efforts were made by the Director to encourage the support of some administrations as regards the provision of the special transmission facilities.

Until shortly before the Final Meeting of Study Group 6, no definite proposals for the provision of transmission facilities had been received, but about 40 administrations and organizations expressed interest in participation and one third of these gave an early indication of their intention to host and provide the equipment for at least one receiver system. During the Final Meetings definite statements were made by two administrations concerning transmission facilities, but the Study Group considered that this was insufficient and too late for an intensive campaign to be conducted in time for the exploitation of the results for the proposed WARC HFBC 1993. Nevertheless the Study Group considers that there is merit in undertaking a measurement campaign over a longer time period, and that for this purpose the requirement for 5 frequency agile transmitters could be relaxed.

Equipment is commercially available for the assembly of suitable receiving installations, while Report 1149 also gives a sufficient specification for equipments to be constructed or assembled by host administrations and organizations. It is expected that the measurement campaign will start during 1990 and that new measurement results will be accumulated which will enable a progressive improvement in the prediction method to be studied in later years.

Nevertheless studies have continued with regard to the HF prediction method of Report 894 and the use of this method is now recommended (Recommendation 533). IWP 6/1 has been given the task of comparing this method and the method adopted by WARC HFBC-87 with the available data bank and of producing two reports: the first for consideration by the Plenary Assembly and the second to be prepared 17 months prior to the start of the WARC HFBC 1993. Resolution 112, is proposed so that the second report from IWP 6/1 may be formally submitted to the Conference.

3.2 *WARC 1992*

Study Group 6 will provide relevant information for the technical preparations for WARC 1992 and in the first instance is working with Joint Interim Working Party 10-3-6-8/1.

3.3 *Proposed regional administrative radio conference for VHF/UHF frequency sharing in Region 3 (CARR-3)*

Study Group 6 provided information on ionospheric propagation at VHF and UHF for use in the technical preparations for this proposed conference.

4. **Interim Working Parties**

Some of the Interim Working Parties in Study Group 6 comprise small groups of experts who undertake long-term studies by correspondence, or who may take advantage of other international meetings for a short IWP meeting. Others however, notably IWPs 6/1 and 6/14, have had a heavy workload and have held meetings to progress the activities.

4.1 *IWP 6/1* (Chairman: Mr. P.A. Bradley, United Kingdom)

IWP 6/1 is engaged in the progressive improvement of HF prediction methods and their validation, and has paid close attention to the specification of HF measurement techniques and the normalization of results for measurement/prediction comparison purposes. The IWP has held annual meetings and had proposed significant improvements to Recommendation 533 and a number of detailed technical reports. At the Final Meetings the IWP was given the additional tasks of undertaking assessments of the performance of the method adopted by WARC HFBC-87, and of recommending improvements to that method. In view of this new work, and also to take account of the developments within IWP 6/14, a new IWP 6/15 has been established and the studies associated with the establishment of measurement data bases has been transferred from IWP 6/1 to the new group.

4.2 *IWP 6/4* (Chairman: Mr. J.C.H. Wang, United States of America)

Recent work by IWP 6/4 has been in connection with the sky-wave field strength prediction methods required for the Region 2 administrative radio conferences for medium frequency broadcasting. As a result of these regional studies, there are now significant differences between the methods applied in Regions 1, 2 and 3. Consequently IWP 6/4 now has terms of reference to study methods suitable for world-wide applications, making use of data collected in all parts of the world. The IWP has met as the opportunity arose during the course of other meetings in Region 2.

4.3 *IWP 6/5* (Chairman: Dr. J. Belrose, Canada)

This small specialist IWP is concerned with the estimation of sky-wave field strength at frequencies below about 500 kHz. Progress has been modest since there is only a small amount of research being undertaken for this frequency range throughout the world. Nevertheless significant improvements are progressively made to the appropriate Reports, such that it has been appropriate to adopt a new Recommendation 684. The IWP works entirely by correspondence.

4.4 *IWP 6/7* (Chairman: Dr. L. MacNamara, Australia)

IWP 6/7, which has worked entirely by correspondence, has made major improvements to the texts concerned with short-term forecasting of propagation conditions and with real-time channel evaluation. The results of the work provide a set of authoritative reviews which are of considerable value to those engaged in the operational use of HF communications. Now that the work has been largely completed, it has been concluded that the work on these topics will be made by individual administrations or agencies.

4.5 *IWP 6/8* (Chairman: Dr. A. Giraldez, Argentina)

This IWP has worked entirely by correspondence and has been improving and extending the information available for ionospheric propagation at VHF and UHF, where such modes may constitute a serious form of interference. This is an area where there is little world-wide research although the results may be of considerable significance for broadcasting and mobile systems, using tropospheric or line-of-sight propagation modes. Despite the modest level of activity, the IWP has been maintained so as to encourage the appropriate studies in this important area.

4.6 *IWP 6/14* (Chairman: Dr. Th. Damboldt, Federal Republic of Germany)

The work of this IWP has been described in § 3.1. The IWP has completed its task and proposals for the HF measurement campaign are contained in Decision 84. The IWP has been terminated.

4.7 *IWP 6/15* (Chairman: Professor N. Wakai, Japan)

This new IWP, established at the Final Meetings in 1989, is intended to combine the work on measurement standardization and data bases previously undertaken in IWP 6/1, and the collection of results from the measurement programme defined by IWP 6/14. The extent of the work, and the corresponding potential for significant improvements in HF prediction methods, will depend upon the cooperation of administrations and agencies in undertaking measurement programmes.

5. Working Group activities at the Study Group meetings

As stated earlier the division of work between Working Groups was maintained during the past study cycle.

In the period two new Recommendations have been drafted concerning propagation below 500 kHz and these effectively complete the complement for the topic areas where Recommendations are appropriate. As studies of radio wave propagation and its applications are continuing in a number of administrations, all the Recommendations represent the current state of knowledge and are subject to progressive improvement and refinement in future years. In the past period eight of the existing Recommendations have been revised and two are maintained unchanged. Recommendation 621, prepared for WARC HFBC-87, is proposed for deletion.

Three new Reports have been prepared. 1149 and 1150 relate to the HF field-strength measurement campaign and for standardized procedures for comparing predicted and observed results, and the third, 1151 deals with the equally timely and important topic of the determination of appropriate noise parameters for use in application to system design. Of the existing Reports, 34 have been revised, seven retained unchanged and two deleted.

Working Group 6-J has continued to refine the basic information texts on ionospheric characteristics and propagation, so as to give in the most concise form possible the background required for the application to system planning and design.

Working Group 6-K has largely completed a review of the various aspects of system operation, short-term forecasting and real-time channel evaluation.

Working Group 6-L, which concentrates on the propagation factors which affect system design and planning, has made important advances particularly in the areas of fading and reliability.

Working Group 6-M has had a low level of activity since very few contributions were received for the progressive improvement of radio noise data and for the methods of its application. It will be recalled that in 1986 there was discussion of the relative merits of Report 322-2, on the characteristics and applications of atmospheric radio noise data, and its revised and updated version, Report 322-3. Accordingly Opinion 85 was drafted at the Plenary Assembly which urged administrations and agencies to make measurements of the intensity and other characteristics of atmospheric radio noise, to analyse the results of the measurements, and to evaluate the practical effects of applying the information. In the four-year period only two short contributions on this subject have been received and the Study Group has concluded that the more recent analysis contained in the Report is generally satisfactory. Nevertheless it is clear that further work is needed in this area. The few stations used in the preparation of the maps of atmospheric radio noise were widely spaced and it remains a high priority to obtain new calibrated information and to undertake further refinements of the information presented.

Working Group 6-N has had the heaviest workload of all and has made major advances. The method of HF field-strength prediction, originally developed for HF broadcast planning, has been refined and tested and the Study Group has concluded that this simpler method may now be recommended for use, although the earlier methods contained in Report 252 and its Supplement are retained for use when additional information (for example on mode structure etc.) is required. A major requirement in the further refinement and testing of these methods is the availability of additional field-strength measurement data, and also the establishment of reliable standardized procedures for calibrating and normalizing observational results. Report 1013 had been produced in 1986 which detailed microcomputer based methods for the estimation of HF radio propagation circuit performance. The Study Group has recognized the major advances in microcomputer technology and its almost universal availability and has concluded that there is now no further need to devise a system specifically for microcomputers. The recommended method is available for microcomputer use. Accordingly Report 1013 is no longer required.

Working Group 6-P has continued studies of propagation at MF and lower frequencies. Following completion of the work for the Region 2 MF Planning Conferences, attention has turned to the overall examination of observations and the preparation of improved prediction procedures for world-wide application.

6. Future organization and work

The division of Study Group 6's work into six parts J, K, L, M, N, P, has served the Study Group for the past three Plenary cycles. The new emphasis which this structure provided led to major improvements particularly in the areas of system design and operational considerations. However at the Final Meetings the Study Group concluded that it was now appropriate to rearrange the texts, and consequently to anticipate the future organization of work into new Working Groups, so as to emphasize the application for system planning and design. Accordingly seven new sections are proposed and the texts are presented in this new arrangement. Two of these sections, 6A and 6C deal with ionospheric properties and with propagation and operational forecasting. Those sections deal with the significant factors which need to be borne in mind for radio systems using or influenced by the ionosphere. Some of the aspects of short-term forecasting and real-time channel evaluation have a strong interface with the work of Study Group 3. Section 6B on radio noise is of wide application and gives information covering all frequencies up to at least 1 GHz.

The three sections 6D-6F give information on propagation prediction techniques and applications, subdivided according to frequency. It is in these topics that the major work should be undertaken so that improved Recommendations may be drafted in future.

Section 6G deals with ionospheric propagation measurements and data banks. Although this topic has been studied for many years it is now thought necessary to highlight this as an area needing concerted activity so as to provide reliable information for the future improvement of predictions. As indicated earlier a new IWP, 6/15, has been established.

It is clear that the requirements for propagation prediction techniques depend on the application and the user. Propagation matters cannot be considered in isolation and the experts must work in close association with spectrum managers and planners, so that useful and convenient methods giving appropriate parameters are developed. A further aspect of this is the use of prediction techniques in system design and a gap has been recognized in the available information. Accordingly a proposal has been drafted in Decision 86 that Study Group 6 in conjunction with other relevant Study Groups should establish a group of experts so as to prepare a handbook on aspects of radio system design.

The majority of Study Group 6 texts relate to the performance of narrow-band or analogue systems. Further work is required to extend this information, but also to fill the important gap of providing information relevant to the performance of digital systems. The Study Group has increasingly concentrated on providing information on the characteristics of the ionosphere and propagation which are specifically required by the user, and this emphasis must be increased in the future.

SECTION 6A: IONOSPHERIC PROPERTIES

RECOMMENDATION 532

IONOSPHERIC MODIFICATION BY HIGH POWER TRANSMISSIONS

(Study Programme 28F/6)

(1978)

The CCIR,

CONSIDERING

(a) that it has long been recognized that cross-modulation can occur at LF and MF when the power flux-density of signals in the ionosphere is large (see Report 574);

(b) that is has now been demonstrated that ionospheric modification, particularly in the F-region, can occur as the result of high power flux-density in the ionosphere in the approximate frequency range 2 to 12 MHz, particularly for high radiation angles and for frequencies just below the layer basic MUFs at near vertical incidence; and that such ionospheric modification may allow propagation at frequencies up to about 400 MHz and over distances of up to 4000 km (see Report 728);

(c) that if administrations allow transmitter powers to continue to increase, the ionosphere can be significantly altered with the result that both the services using the ionosphere as a propagation medium and VHF ground-wave services may experience deterioration of reception,

UNANIMOUSLY RECOMMENDS

1. that attention be paid to, and measures be taken to minimize excessive power flux-densities at ionospheric heights for frequencies up to approximately 12 MHz;

2. that the information contained in Reports 574 and 728 be studied when considering facilities which might produce such higher power flux-densities;

3. that administrations conduct further studies of these effects.

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SECTION 6B: RADIO NOISE

RECOMMENDATION 372-5

USE OF DATA ON RADIO NOISE

(Question 29/6)

(1951-1953-1956-1959-1963-1974-1978-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that Report 322 (Geneva, 1963) was based on data obtained from a network of 16 recording stations from July 1957 to October 1961 and, with a minor revision, was reissued as Report 322-2 (Geneva, 1982);

(b) that the World Administrative Radio Conference (WARC-79), recognizing the significant amount of additional data available, adopted Recommendation No. 68 requesting that the CCIR encourage and assist in initiating additional studies of radio noise and recommending that administrations continue to provide rapid dissemination of noise data and of the related prediction;

(c) that Interim Working Party 6/2 (Decision 21) was requested to revise Report 322-2 (Geneva, 1982) and that the revised version, Report 322-3 (Dubrovnik, 1986) was subsequently approved;

(d) that the Second Session of the World Administrative Radio Conference for the Planning of the HF Bands Allocated to the Broadcasting Service (Geneva, 1987) adopted for use values for the atmospheric radio noise levels based upon Report 322-2 (Geneva, 1982);

(e) that additional information on the measurement and use of radio noise is given in Reports 254 and 1151;

(f) that Opinion 85 urges administrations to make measurements of atmospheric radio noise, to analyse the measurement results and to evaluate the practical effects of applying noise information,

UNANIMOUSLY RECOMMENDS

that the information contained in Reports 258, 322, 342, 670 and 720 should be used in assessing the intensity and/or other characteristics of man-made and natural radio noise until new information to justify the revision of these Reports is made available.

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SECTION 6C: IONOSPHERIC PROPAGATION AND OPERATIONAL FORECASTING

RECOMMENDATION 373-6*

DEFINITIONS OF MAXIMUM AND MINIMUM TRANSMISSION FREQUENCIES

(Question 25/6)

(1959-1963-1966-1970-1974-1978-1982-1990)

The CCIR,

CONSIDERING

that prediction services, scientists and operators have different requirements for definitions of the maximum and minimum transmission frequency,

UNANIMOUSLY RECOMMENDS that the following definitions should be used:

1. *operational MUF*, or simply *MUF*, is the highest frequency that would permit acceptable performance of a radio circuit by signal propagation via the ionosphere between given terminals at a given time under specified working conditions;

lowest usable frequency (LUF) is the lowest frequency that would permit acceptable performance of a radio circuit by signal propagation via the ionosphere between given terminals at a given time under specified working conditions.

Note 1 – Acceptable performance may for example be quoted in terms of maximum error ratio or required signal/noise ratio.

Note 2 – Specified working conditions may include such factors as antenna types, transmitter power, class of emission and required information rate;

2. *basic MUF* is the highest frequency by which a radio wave can propagate between given terminals, on a specified occasion, by ionospheric refraction alone.

ANNEX I

1. The *Optimum Working Frequency* (OWF or FOT) is the lower decile of the daily values of operational MUF at a given time over a specified period, usually a month. That is, it is the frequency that is exceeded by the operational MUF during 90% of the specified period.

2. Where the basic MUF is restricted to a particular ionospheric propagation mode, the values may be quoted together with an indication of that mode (for example, 1E MUF, 2F2 MUF).

If the extraordinary component of the wave is involved, then this is noted (for example, 1F2 MUF(X)). Absence of a specific response to the magnetoionic component implies that the quoted value relates to the ordinary wave.

It is sometimes useful to quote the ground range for which the basic MUF applies. This is indicated in kilometres following the indication of the mode type (for example, 1F2 (4000) MUF(X)).

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* The Director, CCIR, is requested to bring this Recommendation to the attention of International Radio Science Union (URSI) and Study Groups 3, 7, 8 and 10 and the CCV.

RECOMMENDATION 313-6

EXCHANGE OF INFORMATION FOR SHORT-TERM FORECASTS AND TRANSMISSION OF IONOSPHERIC DISTURBANCE WARNINGS

(Question 27/6)

(1951-1959-1966-1974-1978-1982-1986-1990)

The CCIR,

CONSIDERING

that some radiocommunication services would benefit from having the earliest possible warnings of the probable onset of disturbances to ionospheric propagation,

UNANIMOUSLY RECOMMENDS

1. that each country participating in radio propagation research should designate an official agency for the reception, coordination and exchange of information required for the preparation of short-term forecasts, and for liaison with corresponding agencies in other countries;

2. that such information should be forwarded to the above agencies by the most direct means of telecommunication;

3. that data needed for short-term forecasting within 48 hours should be disseminated in accordance with the International Ursigram and World Days Service (IUWDS) decisions by suitable available communication channels, while other data should be disseminated by ordinary post or airmail, or, if requested, by radio or other rapid means of communication, and that short regular transmissions giving short-term warnings of ionospheric disturbances should be effected by long-range radio stations;

4. that codes to be used for the above communication and dissemination should be fully standardized in accordance with IUWDS decisions and actions;

5. that administrations and operating agencies using the above services should be invited to compare the forecasts with the actual behaviour of radio circuits, to evaluate the accuracy of the forecasts, and to provide records and make any suggestions which might assist the studies undertaken to improve the methods used;

6. that it is desirable that a common method, based on the work on Question 27/6 be adopted to describe ionospheric perturbations and variations, for correlation with forecasts and the behaviour of operating radio services;

7. that, where administrations have provided facilities for the rapid interchange of information in connection with the IUWDS, these facilities should be maintained, and, if necessary, extended in the future.

ANNEX I

AVAILABILITY AND EXCHANGE OF BASIC DATA FOR RADIO PROPAGATION FORECASTS

1. Introduction

Propagation of radio signals in the range 3 to 30 MHz is practicable over any but the shortest distances, mainly because of the possibility of obtaining ionospheric and ground reflections which result in small values of attenuation. Satisfactory communications for a given circuit can generally be obtained if the operating frequency lies between a lower (LUF) and an upper (operational MUF) frequency limit. These are determined by ionospheric characteristics. The operational range of frequencies has been found to be even more restricted with some forms of high capacity communication systems.

Since only a limited range of frequencies can be used, it is desirable to have, as far in advance as possible, information on the probable values of these upper and lower limits, as well as short-term forecasts and disturbance warnings. Collectively, these predictions (long-term) and forecasts (short-term) and disturbance warnings provide information for planning and operating personnel, that can be utilized in making the most economical use of the limited resources of equipment and frequency spectrum. The long and medium-term predictions are indicative of representative ionospheric conditions, so that it is extremely useful to operating personnel to be warned of impending ionospheric disturbances in order that traffic can be re-routed, instructions can be issued in advance to cover temporary adjustments in the normal operating frequency, and the performance of other systems affected by the ionosphere can be assessed.

2. Available data for radio-propagation forecasts

2.1 *Long-term predictions*

Organizations in several countries now prepare predictions of ionospheric conditions and ionospheric indices from one month up to twelve months in advance (see Table I); for general planning purposes, predictions for a complete solar cycle are also made by some organizations. These predictions are for representative ionospheric conditions. The information is usually issued in the form of charts which are applicable to any part of the world and are available for interchange between the organizations undertaking this service.

2.2 *Forecasts of disturbances*

Organizations in several countries now prepare forecasts of ionospheric disturbances from a few hours to twenty-seven days in advance (see Table I). These forecasts are supplemental to the long-term predictions, since the occurrence of ionospheric disturbances, which cannot be forecast for long periods in advance, may modify considerably the frequency range within which satisfactory operation can be maintained on a particular circuit. Operating organizations have shown interest in these short-term forecasts to such an extent that they are now being regularly transmitted by radio at scheduled times (see Table I).

2.3 *Working documents for long-term predictions*

The CCIR Atlas of ionospheric characteristics, Report 340, is the source of basic MUF and FOT for use with predicted 12-month running mean sunspot numbers R_{12} in making long-term predictions for any part of the world.

3. Exchange of basic data used in short-term forecasts

3.1 For many years, scientific information of direct interest to those concerned with ionospheric forecasts and disturbances has been broadcast by certain countries, in programmes known as Ursigrams. Since 1962, through the International Ursigram and World Days Service (IUWDS) (a Permanent Service of URSI in association with IAU and IUGG adhering to the Federation of Astronomical and Geophysical Services), these data are collected, coordinated and exchanged by rapid means through suitable interchange synoptic codes. These programmes provide a means of exchange of summary information required within 48 hours, after its collection, for the preparation of short-term forecasts and similar urgent purposes. These exchanges are made through regional networks, composed of observatories, laboratories, communication agencies and regional centres. The regional centres in turn exchange, once a day, summaries of information on solar flares, sudden ionospheric disturbances, solar corona and radio emission, sunspots, ionospheric and magnetic activity, as well as forecasts. The regional warning centres (RWC) in Australia, France, the Federal Republic of Germany, Japan, and the U.S.S.R., plus associate regional centres in the Czechoslovak Socialist Republic, India and Poland (People's Republic of) collect data in their regions and forward them by telegraph to the IUWDS World Warning Agency (at Boulder, Colorado, USA), which has also collected data from its region. The IUWDS World Warning Agency makes the final decisions, having advice available from the other centres, whether or not to declare a world-wide GEOPHYSICAL ALERT (issued shortly after an exceptional solar or geophysical event has occurred or started) – a period during which many geophysical stations carry out special observing programmes. These decisions are distributed throughout the world to scientific stations participating in the programme by various rapid means, in particular over the meteorological teleprinter networks coordinated by the WMO.

3.2 Types of data exchanged among the various regional centres are those concerning solar flares, solar corona, solar radio emission, cosmic rays, critical frequencies of the ionosphere, ionospheric disturbances, terrestrial magnetism and radio-propagation quality. Data are collected and transmitted in simple synoptic codes. Code booklets are available from Dr. R. Thompson, Chairman, IUWDS Steering Committee, IPS Radio and Space Services, P.O. Box 702, Darlinghurst 2010, New South Wales, Australia, or Mr. G. Heckman, Secretary for Ursigrams, IUWDS Steering Committee, NOAA, Boulder, Colorado 80303, USA. The regional centres from which details may be obtained concerning data and schedules of broadcasts and reports are listed in the Part E of the IUWDS Synoptic Codes for Solar and Geophysical Data, Third Revised Edition, 1973.

3.3 Table I lists the centralizing agencies, which have been designated for the reception, coordination, liaison and exchange of information relating to radio propagation.

TABLE I – *List of organizations concerned with the exchange of data and the issuing of forecasts of propagation conditions and ionospheric indices*

A: an agency for the general exchange of information on propagation.

RC: a regional centre of the IUWDS for the rapid exchanges of data required for short-term forecasts of disturbances.

L: the organization issues long-term propagation predictions. The period ahead for which predictions are made as shown (in months).

S: the organization issues short-term forecasts of disturbances.

I: the organization issues long-term predictions of ionospheric indices. The period ahead for which predictions are made is as shown (in months).

Country	Organization	Address	A	RC	L	S	I
Germany (Federal Republic of)	Deutsche Bundespost TELEKOM Forschungsinstitut	Deutsche Bundespost, TELEKOM Forschungsinstitut Postfach 5000 D 6100 Darmstadt Telex: 419209 Telefax: +49 6151 834570	x	x	3	x	
Argentina	LIARA	LIARA Av. Libertador No. 327 1638 Vicente López, (B.A.)	x		6		
Australia	IPS	IPS Radio and Space Services P.O. Box 1548 Chatswood 2057 Telex: AA 20663 Telefax: +61 2 414 8340		x	3	x	12
Belgium		Chef du service du Rayonnement Institut royal météorologique 3, Avenue Circulaire, Uccle, Brussels	x				
Brazil	CTA/ITA	Centro técnico Aeroespacial São José dos Campos São Paulo	x		1		
	I.Pg.M.	Instituto de Pesguisas da Marinha Ministério da Marinha Rio de Janeiro			1		
Canada	Department of Communications	Telecommunications Regulatory Service Engineering Support Division 1241 Clyde Avenue Ottawa, Ontario	x				
China (People's Republic of)	CRIRP	China Research Institute of Radiowave Propagation P.O. Box 138 Xinxiang, Henan Telex: Xinxiang 2525	x			x	12
Spain		Dirección General de Telecomunicaciones, Madrid	x				

TABLE I *(continued)*

Country	Organization	Address	A	RC	L	S	I
United States	NOAA Environmental Research Laboratories	Space Environment Services Center NOAA R/E/SE2 325 Broadway Boulder, Colorado 80303 Telex: 888776	x	x		x ([1])	
	NOAA Environmental Data and Information Services	World Data Center A for Solar-Terrestrial Physics NOAA E/GC2 325 Broadway Boulder, Colorado 80303			6 see Note		
	National Telecommunications and Information Administration	Institute for Telecommunication Sciences 325 Broadway Boulder, Colorado 80303	x				
France	CNET	Service des Ursigrammes Observatoire de Paris F-92190 Meudon Télex: 200590	x	x		x	
		Service des Prévisions Ionosphériques CNET 2, route de Trégastel B.P. 40 F-22301 Lannion Cedex Télex: 950327	x		3	x	
India	Council of Scientific and Industrial Research	The Secretary Radio Research Committee National Physical Laboratories Hillside Road, New Delhi, 12	x	x	6		
	India Meteorological Department	Kodaikanal Observatory				x	
	All India Radio	Research Department, All India Radio Indraprastha Estate, New Delhi-1	x				
Israel	Radio Observatory	P.O. Box 911 Haifa 31008	x		1		
Italy		Istituto Nazionale di Geofisica Reparto Ionosferico Via di Villa Ricotti 42 00161 Rome Telex: 625835 Telefax: 06-429040	x		3		
Japan	CRL	Communications Research Laboratory Ministry of Posts and Telecommunications 2-1, Nukui-kita-machi, 4-chome Koganeishi, Tokyo, 184 Telex: 2832611	x	x		x ([2])	

([1]) Solar and geophysical information radiated from WWV.

([2]) Warnings radiated from JJY.

Note – World Data Center A for Solar-Terrestrial Physics receives and distributes ionospheric data from a few geographical areas not directly represented through membership in the ITU.

TABLE I *(continued)*

Country	Organization	Address	A	RC	L	S	I
Mexico	SCT	Dirección General de Telecomunicaciones Estación de sondeo ionosférico Xola y Universidad, Mexico, (12) DF	x				
Netherlands	PTT	Afdeling "Ionosfeer en Radioastronomie" St. Paulus St. 4, Leidschendam	x				
Poland (People's Republic of)	Polish Academy of Sciences Space Research Centre	Helio-Geophysical Prediction Service Polish Academy of Sciences Space Research Centre Ordona 21 01-293, Warsaw Télex: 815670 cbkpl		x		x	
German Democratic Republic	RFZ	Rundfunk- und Fernsehtechnisches Zentralamt Berlin-Adlershof, Agastrasse Telex: 0158720	x		3		
	HHI	Heinrich-Hertz-Institut für solar-terrestrische Physik Juliusruh/Rügen Télex: 318422	x			x	
United Kingdom	Rutherford Appleton Laboratory	World Data Centre CI/STP Rutherford Appleton Laboratory Chilton, Didcot Oxfordshire, OX11 OQX Telex: 83159	x				12
	GEC-Marconi Research Centre	GEC-Marconi Research Centre West Hanningfield Road Great Baddow Chelmsford Essex CM2 8HN Telex: 995016 Telefax: +44 245 75244			6	x	
Republic of South Africa	CSIR	National Institute for Telecommunications Research 18a Gill Street P.O. Box 3718 Observatory Johannesburg, 2000	x		1		
Sweden		Swedish Telecom Radio S-13680 Haninge Telex: 14970 Telefax: 7074684	x		3		
Czechoslovac Socialist Republic		Geophysical Institute Academy of Sciences Bočni 2, 14100 Praha 4, Spořilov		x			
USSR	Hydrometeorological Service	Hydrometeorological Service Institute of Applied Geophysics Moscow	x	x	3	x (3)	

(3) Warnings radiated from RDZ and RND.

SECTION 6D: IONOSPHERIC PROPAGATION PREDICTION AT FREQUENCIES BELOW ABOUT 1.6 MHz

RECOMMENDATION 435-6*

PREDICTION OF SKY-WAVE FIELD STRENGTH BETWEEN 150 AND 1600 kHz

(Study Programme 31D/6)

(1966-1970-1974-1978-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that there is a need to give guidance to engineers in the planning of broadcast services in the LF and MF bands;

(b) that it is important, for stations working in the same or adjacent frequency channels, to determine the minimum geographical separation required to avoid interference resulting from long-distance ionospheric propagation;

(c) that the method given in Annex I is based on the statistical analyses of field-strength measurements for 266 paths distributed throughout the world, supplemented by the results of analyses for geographical areas from which individual path data are not available,

RECOMMENDS

that the method provided in Annex I be adopted for provisional use, taking particular note of the cautions on accuracy in its application to certain regions stated therein.

ANNEX I

SKY-WAVE FIELD STRENGTH PREDICTION METHOD FOR THE FREQUENCY RANGE 150 TO 1600 kHz

List of symbols

- A: A parameter defined in § 2.
- b: Solar-activity factor given in § 2.6.
- d: Ground distance between transmitter and receiver (km).
- E: Annual median field strength for a given cymomotive force (c.m.f.), V, and at a given time t, relative to sunset or sunrise as appropriate (dB(μV/m)).
- E_0: Annual median field strength at the reference time defined in § 2 (dB(μV/m)).
- f: Frequency (kHz).
- G_0: Sea gain for a terminal on the coast (dB).
- G_H: Transmitting antenna gain factor due to horizontal directivity (dB).
- G_S: Sea gain for a terminal near the sea (dB).
- G_V: Transmitting antenna gain factor due to vertical directivity (dB).
- h: Transmitting antenna height (Fig. 1).

* The Administration of the People's Republic of China reserves its opinion on this Recommendation.

I: Magnetic dip angle, N or S (degrees).

k, k_R: Loss factors in § 2.6.

L_p: Excess polarisation coupling loss (dB).

L_t: Hourly loss factor (dB).

P: Radiated power (dB(1 kW)).

p: Slant propagation distance (km).

Q_1, Q_2: Sea-gain parameters given in § 2.3.

R: Twelve-month smoothed international relative sunspot number.

r_1, r_2: Parameters defined in § 2.3.

s_1: Distance of terminal from sea, measured along great-circle path (km).

s_2: Distance of terminal from next section of land, measured along great-circle path (km).

t: Time relative to sunset or sunrise (hours).

V: Transmitter cymomotive force (dB(300 V)).

θ: Direction of propagation relative to magnetic East-West (degrees).

λ: Wavelength.

Φ: A geomagnetic latitude parameter.

Φ_T: Geomagnetic latitude of transmitter (degrees, positive in northern hemisphere negative in southern hemisphere).

Φ_R: Geomagnetic latitude of receiver (degrees, positive in northern hemisphere negative in southern hemisphere).

1. Introduction

This method of prediction gives the night-time sky-wave field strength produced for a given power radiated from one or more vertical antennas, when measured by a loop antenna at ground level aligned in a vertical plane along the great-circle path to the transmitter. It applies for paths of lengths up to 12 000 km in the LF and MF bands. However, at LF it was only verified for paths of up to 5000 km. The accuracy of prediction varies from region to region and may be improved in certain regions by applying modifications such as those shown in § 6. In any case the method should be used with caution for geomagnetic latitudes greater than 60°.

Figures 1, 2 and 3 are an essential part of the prediction method. Geomagnetic maps are included for convenience in Figs. 11, 12 and 16. The remaining Figs. 4 to 10, 13 to 15, 17 and Appendix I to Annex I, provide additional information to simplify the use of the method.

2. Annual median night-time field strength

The predicted sky-wave field strength is given by:

$$E = V + E_0 - L_t = V + G_S - L_p + A - 20 \log p - 10^{-3} k_R \, p - L_t \qquad (1)$$

where:

E: annual median of half-hourly median field strengths (dB(μV/m)) for a given transmitter cymomotive force, V, and at a given time, t, relative to sunset or sunrise as appropriate,

E_0: annual median of half-hourly median field strengths (dB(μV/m)) for a transmitter cymomotive force of 300 V at the reference time defined in § 2.1,

V: transmitter cymomotive force, dB above a reference cymomotive force of 300 V (see § 2.2),

G_S: sea-gain correction (dB), (see § 2.3),

L_p: excess polarization-coupling loss (dB), (see § 2.4),

A: $106.6 - 2 \sin \Phi$, where Φ is defined by equation (12),

p: slant-propagation distance (km), (see § 2.5),

k_R: loss factor incorporating effects of ionospheric absorption, focusing and terminal losses, and losses between hops on multi-hop paths (see § 2.6),

L_t: hourly loss factor (dB), (see § 2.7).

To facilitate calculation, Fig. 4 shows the quantity $A - 20 \log p$, for $\Phi = 40°$ as a function of ground distance, d, whereas Figs. 5 to 10 show E_0 as a function of ground distance, d, for various frequencies and for various geomagnetic latitudes when G_S, L_p and R are all zero.

2.1 *Reference time*

The reference time is taken as six hours after the time at which the Sun sets at a point S on the surface of the Earth. For paths shorter than 2000 km, S is the mid-point of the path. On longer paths, S is 750 km from the terminal where the sun sets last, measured along the great-circle path. The relation between ground distance and the geographic coordinates of points on the path is given in Report 252.

2.2 *Cymomotive force*

The cymomotive force V is given as:

$$V = P + G_V + G_H \tag{2}$$

where:

P: radiated power, dB (1 kW),

G_V: transmitting antenna gain factor (dB) due to vertical directivity, given in Fig. 1,

G_H: transmitting antenna gain factor (dB) due to horizontal directivity. For directional antennae, G_H is a function of azimuth. For omnidirectional antennas, $G_H = 0$.

2.3 *Sea gain*

G_S is the additional signal gain when one or both terminals are situated near the sea, but it does not apply to propagation over fresh water. G_S for a single terminal is given by:

$$G_S = G_0 - c_1 - c_2 \qquad \text{for} \qquad (c_1 + c_2) < G_0 \tag{3}$$

$$G_S = 0 \qquad \text{for} \qquad (c_1 + c_2) \geqslant G_0 \tag{4}$$

where:

G_0: gain when the terminal is on the coast and the sea is unobstructed by further land,

c_1: correction to take account of the distance between the terminal and the sea,

c_2: correction to take account of the width of one or more sea channels, or the presence of islands.

If both terminals are near the sea, G_S is the sum of the values for the individual terminals.

G_0 is given in Fig. 2 as a function of d for LF and MF. At MF, $G_0 = 10$ dB when $d > 6500$ km.

The correction c_1 is given by

$$c_1 = \frac{s_1}{r_1} G_0 \tag{5}$$

where:

s_1: distance of terminal from sea, measured along great-circle path (km),

$r_1 = 10^3 G_0^2 / Q_1 f$ (km),

f: frequency (kHz),

$Q_1 = 0.30$ at LF and 1.4 at MF.

The correction c_2 is given by

$$c_2 = \alpha \, G_0 \left(1 - \frac{s_2}{r_2}\right) \quad \text{si} \quad s_2 < r_2 \tag{6}$$

$$c_2 = 0 \qquad\qquad \text{si} \quad s_2 \geqslant r_2 \tag{7}$$

where,

s_2 : distance of terminal from next section of land, measured along great-circle path (km),

$r_2 = 10^3 G_0^2 / Q_2 f$ (km),

$Q_2 = 0.25$ at LF and 1.2 at MF,

α : proportion of land in the section of path between r_2 and s_2 ($0 < \alpha \leqslant 1$).

If a computer is used but a terrain data bank is not available to calculate α, then α should be made equal to 0.5, which implies that land and sea are present in equal proportions in the section of path between r_2 and s_2.

To facilitate calculation, Fig. 14a shows r_1, the greatest distance from the sea for which sea gain has to be calculated, and Fig. 14b shows r_2, the greatest distance to the next section of land for which the correction c_2 is required, for various frequencies.

2.4 *Polarization coupling loss*

L_p is the excess polarization coupling loss. At LF, $L_p = 0$. At MF, L_p for a single terminal is given by one of the following two formulae:

$$\begin{aligned} &\text{If } I \leqslant 45^\circ : L_p = 180\,(36 + \theta^2 + I^2)^{-1/2} - 2 \quad \text{dB} \\ &\text{If } I > 45^\circ : L_p = 0 \end{aligned} \tag{8}$$

where I is the magnetic dip, N or S, in degrees at the terminal and θ is the path azimuth measured in degrees from the magnetic E-W direction, such that $|\theta| \leqslant 90^\circ$. L_p should be evaluated separately for the two terminals, because of the different θ and I that may apply, and the two L_p values added. The most accurate available values of magnetic dip and declination (e.g. see Figs. 11 and 12) should be used in determining θ and I.

Figure 13 shows values of L_p calculated from equation (8).

2.5 *Slant propagation distance*

For paths longer than 1000 km, p is approximately equal to the ground distance d (km). For shorter paths

$$p = (d^2 + 40\,000)^{1/2} \tag{9}$$

Equation (9) may be used for paths of any length with negligible error. It should be used in all cases where the distances considered are both above and below 1000 km, to avoid discontinuities in field strength as a function of distance.

2.6 *Loss factor*

The loss factor k_R is given by

$$k_R = k + 10^{-2}\, bR \tag{10}$$

where R = twelve-month smoothed International Relative Sunspot Number. At LF, $b = 0$. At MF, $b = 4$ for North American paths, 1 for Europe and Australia and 0 elsewhere.

The basic loss factor k is given by:

$$k = 3.2 + 0.19\, f^{0.4} \tan^2(\Phi + 3) \tag{11}$$

where f = frequency (kHz). If $\Phi > 60^\circ$, equation (11) is evaluated for $\Phi = 60^\circ$. If $\Phi < -60^\circ$, equation (11) is evaluated for $\Phi = -60^\circ$. Figure 15 shows values of k calculated from equation (11) according to these rules.

For paths shorter than 3000 km:

$$\Phi = 0.5\,(\Phi_T + \Phi_R) \tag{12}$$

where Φ_T and Φ_R are the geomagnetic latitudes at the transmitter and receiver respectively, determined by assuming an Earth-centred dipole field model with northern pole at 78.5° N, 69° W geographic co-ordinates. The equation for Φ_T and Φ_R is given in Fig. 16 and Φ_T and Φ_R are taken as positive in the northern hemisphere and negative in the southern hemisphere. Paths longer than 3000 km are divided into two equal sections which are considered separately. The value of Φ for each half-path is derived by taking the average of the geomagnetic latitudes at one terminal and at the mid-point of the whole path, the geomagnetic latitude at the mid-point of the whole path being assumed to be the average of Φ_T and Φ_R. As a consequence:

$$\Phi = (3\Phi_T + \Phi_R)/4 \text{ for the first half of the path and} \tag{13}$$

$$\Phi = (\Phi_T + 3\Phi_R)/4 \text{ for the second half.} \tag{14}$$

The values of k calculated from equation (11) for the two half-paths are then averaged and used in equation (10).

2.7 *Hourly loss factor*

The hourly loss factor, L_t, is given in Fig. 3. The time t is the time in hours relative to the sunrise or sunset reference times as appropriate. These are taken at the ground at the mid-path position for $d < 2000$ km and at 750 km from the terminal where the Sun sets last or rises first for longer paths. Equations generally equivalent to these curves to within 0.5 dB, are given in § 1 of Appendix I. Figure 3 represents the average annual diurnal variation. At LF, it should be used with caution because of the large seasonal variations which are known to occur, especially in temperate latitudes.

Figure 17 shows sunset and sunrise times for a range of geographic latitudes. Equations equivalent to these sunset and sunrise curves are given in § 2 of Appendix I.

3. Day-to-day and short-period variations of night-time field strength

The field strength exceeded for 10% of the total time on a series of nights at a given season, during short periods centred on a specific time, is

6.5 dB greater at LF,

8 dB greater at MF

than the value of E_0 given in § 2. Larger values may be observed at the peak of the solar cycle.

4. Seasonal variation of night-time field strength

At night, MF sky-waves propagating in temperate latitudes are strongest in spring and autumn and are weakest in summer and winter, the summer minimum being the more pronounced. The overall variation may be as much as 15 dB at the lowest frequencies in the MF band, decreasing to about 3 dB at the upper end of the band. At LF the seasonal variation at night has the opposite trend, with a pronounced summer maximum. The seasonal variation is much smaller in tropical latitudes.

5. Daytime field strength

At LF in Europe the median day-time field strength in winter is 10 dB less than the night-time value of E_0 given in § 2. In summer the daytime field strength is 30 dB less than E_0. The field strength exceeded for 10% of the total time on a series of days in winter, during short periods centred on a specific time, is 5 dB greater than the median day-time value given above.

At MF in Europe the median day-time field strength in winter is 25 dB less than the night-time value of E_0 given in § 2. In summer the day-time field strength is about 60 dB less than E_0.

In spring and autumn in Europe, daytime field strengths at LF and MF have values between the summer and winter values.

6. Accuracy of the method

The accuracy in the ITU Region 2 (the Americas) may be improved by using a reference time of two hours after sunset. Field strengths measured in the United States of America and Brazil, tend to be greater at higher frequencies; the frequency variation given by equation (11) is in the opposite sense.

Equation (6) which describes how G_S is modified by the distance s_2 to the next section of land is derived from theory and must therefore be regarded as tentative until measurements are available.

The method predicts the field strength which is likely to be observed if the transmitter and receiver are situated on ground of average conductivity, typically 3 to 10 mS/m. In certain areas (e.g. see Report 717), the effective ground conductivity can be as low as 0.5 mS/m or as high as 40 mS/m. If the ground conductivity at either terminal is an order of magnitude smaller than 10 mS/m, then the field strength may be up to 10 dB smaller. If the ground conductivity at both terminals is an order of magnitude smaller, then the field-strength reduction will be doubled. The amount of attenuation is a function of path length and is greatest for waves approaching grazing incidence. The method may be improved by using a correction for ground conductivity when it differs significantly from that for average ground, for example by using the information contained in Reports 265 and 575.

The method assumes that reflection takes place only via the E layer, or that E-layer reflections predominate. However, if $f >$ (foE) sec i, where foE is the critical frequency of the E layer and i is the angle of incidence at the E layer, then the wave will penetrate the E layer and be reflected from the F layer. This is most likely to occur at the highest frequencies in the MF band at ground distances less than 500 km, especially late at night and during the sunspot minimum period. The method can still be used provided p is calculated for an F-layer reflection height of 220 km and the cymomotive force V is calculated for the corresponding angle of elevation.

Measurements made in the United States of America suggest that Fig. 3 (hourly loss factor) is likely to be accurate for frequencies near 1000 kHz in a year of low solar activity. As the frequency deviates in either direction from about 1000 kHz, particularly during transition hours, appreciable errors may result. These measurements also suggest that the magnitude of the effect of solar activity at two hours after sunset is considerably greater than that at six hours after sunset. Thus, in a year of high solar activity, the difference between field strengths at six hours after sunset and two hours after sunset can be considerably greater than that shown in Fig. 3

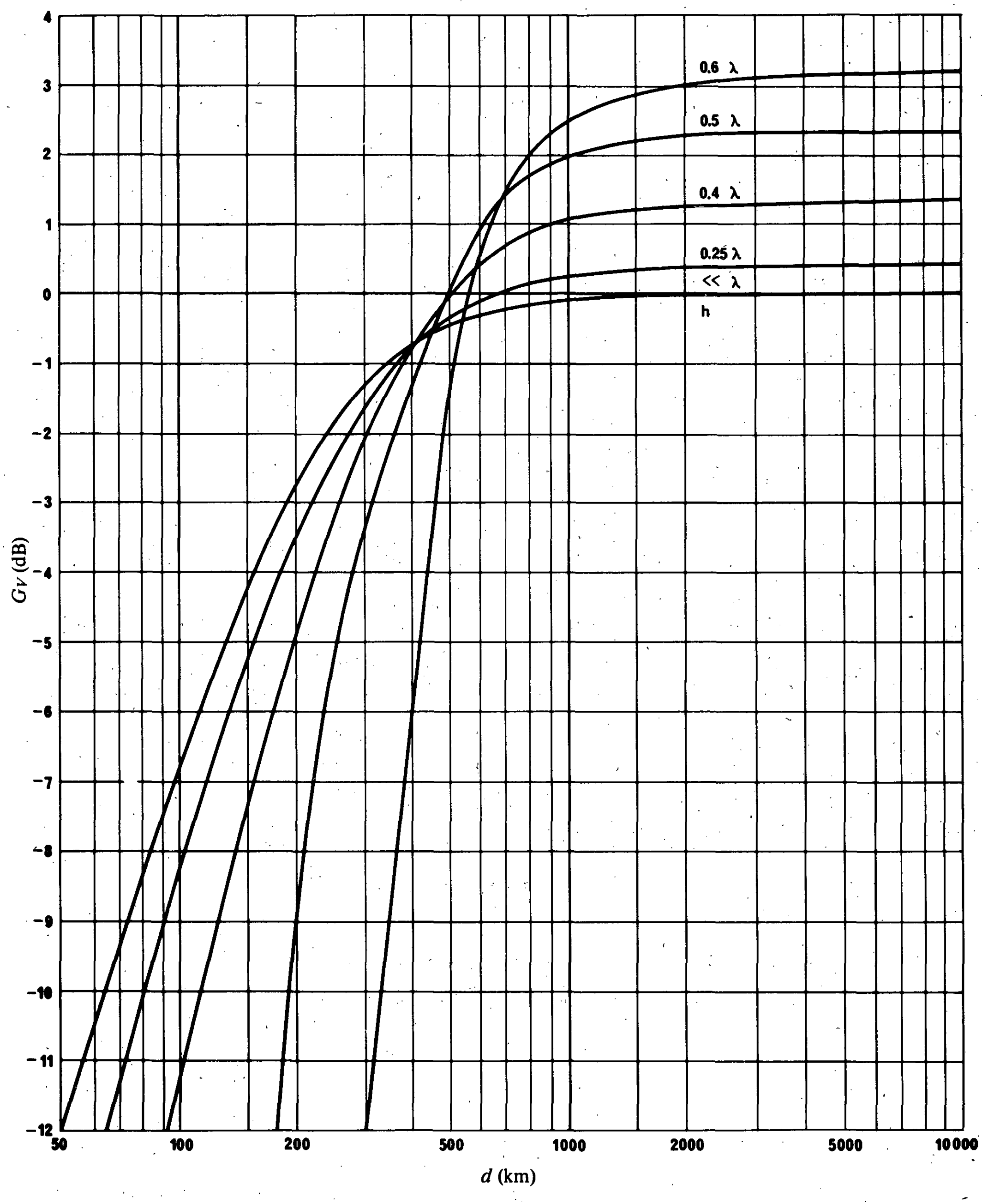


FIGURE 1 – *Transmitting antenna gain factor for single monopoles (G_V)*

h: antenna height

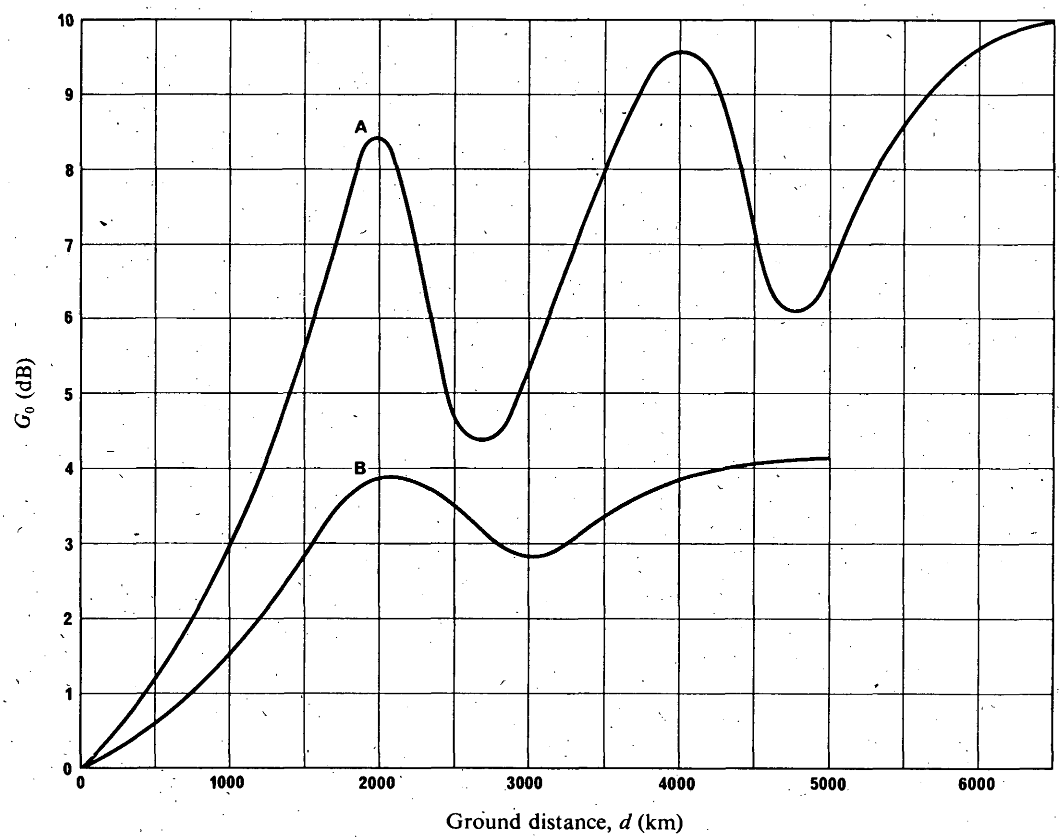


FIGURE 2 – *Sea gain (G_0) for a single terminal on the coast*

A: MF band B: LF band

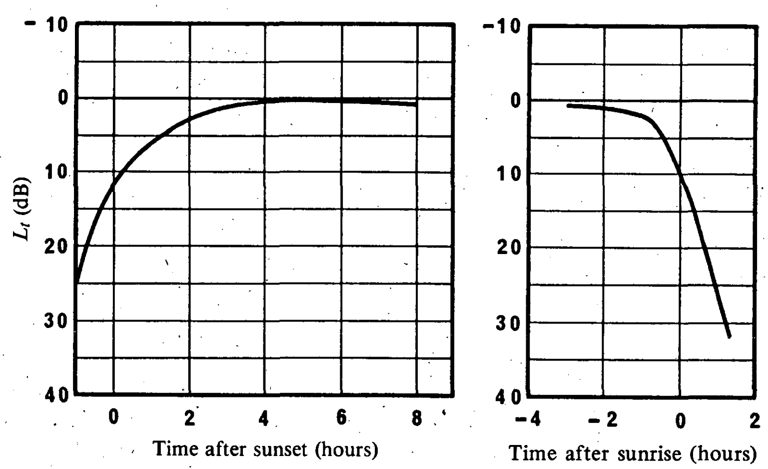


FIGURE 3 – *Hourly loss factor (L_t)*

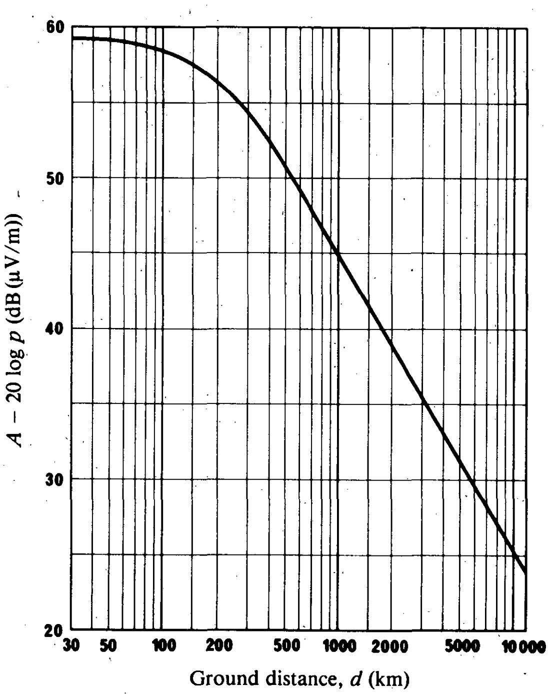
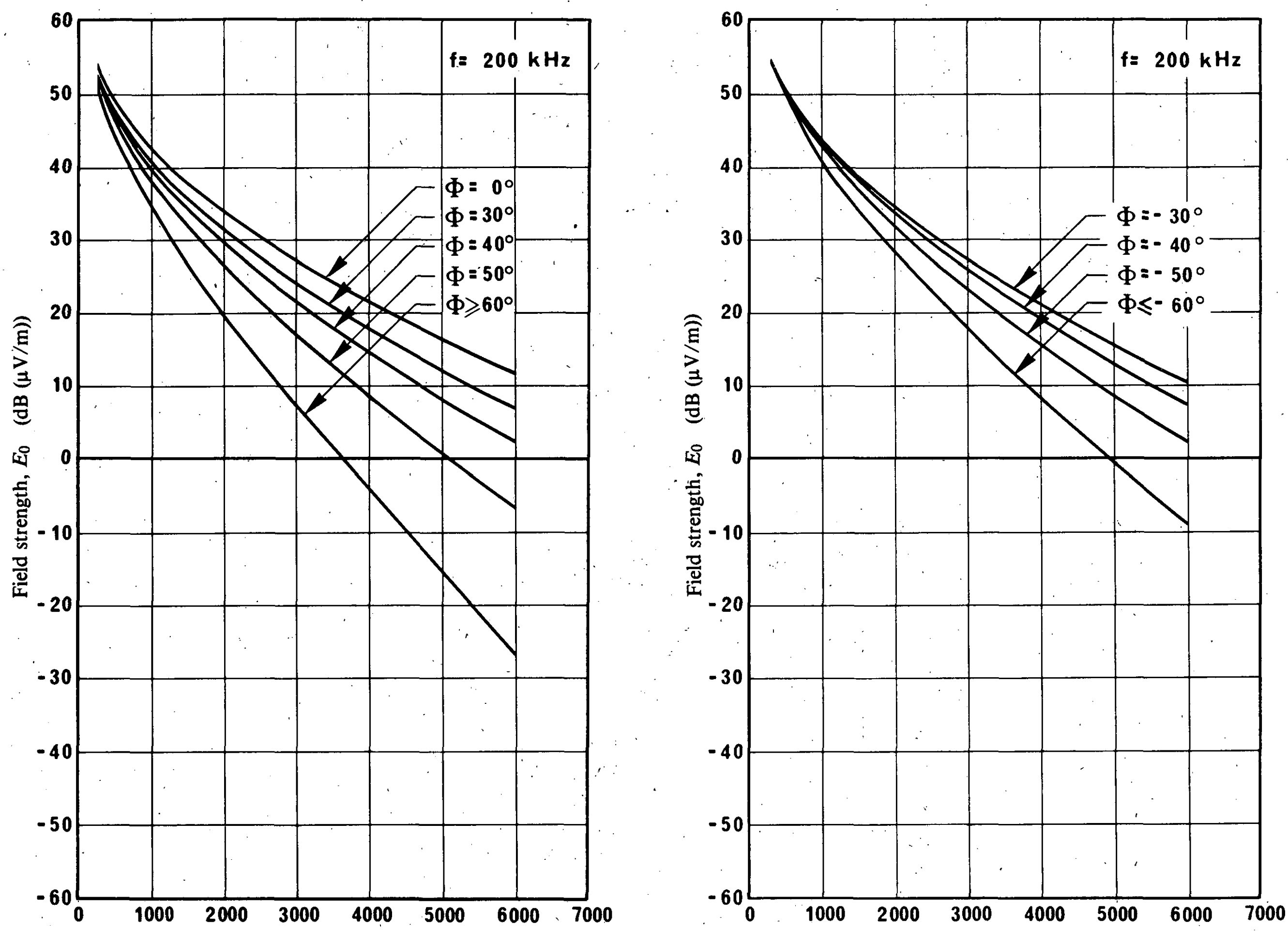


FIGURE 4 – *Basic field strength*

The curves show $A - 20 \log p$
Where $A = 106.6 - 2 \sin \Phi$
$\Phi = 40°$
$p = (d^2 + 40\,000)^{1/2}$



(a) Northern hemisphere
(Φ positive)

(b) Southern hemisphere
(Φ negative)

FIGURE 5 – *Curves showing E_0 for 200 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*

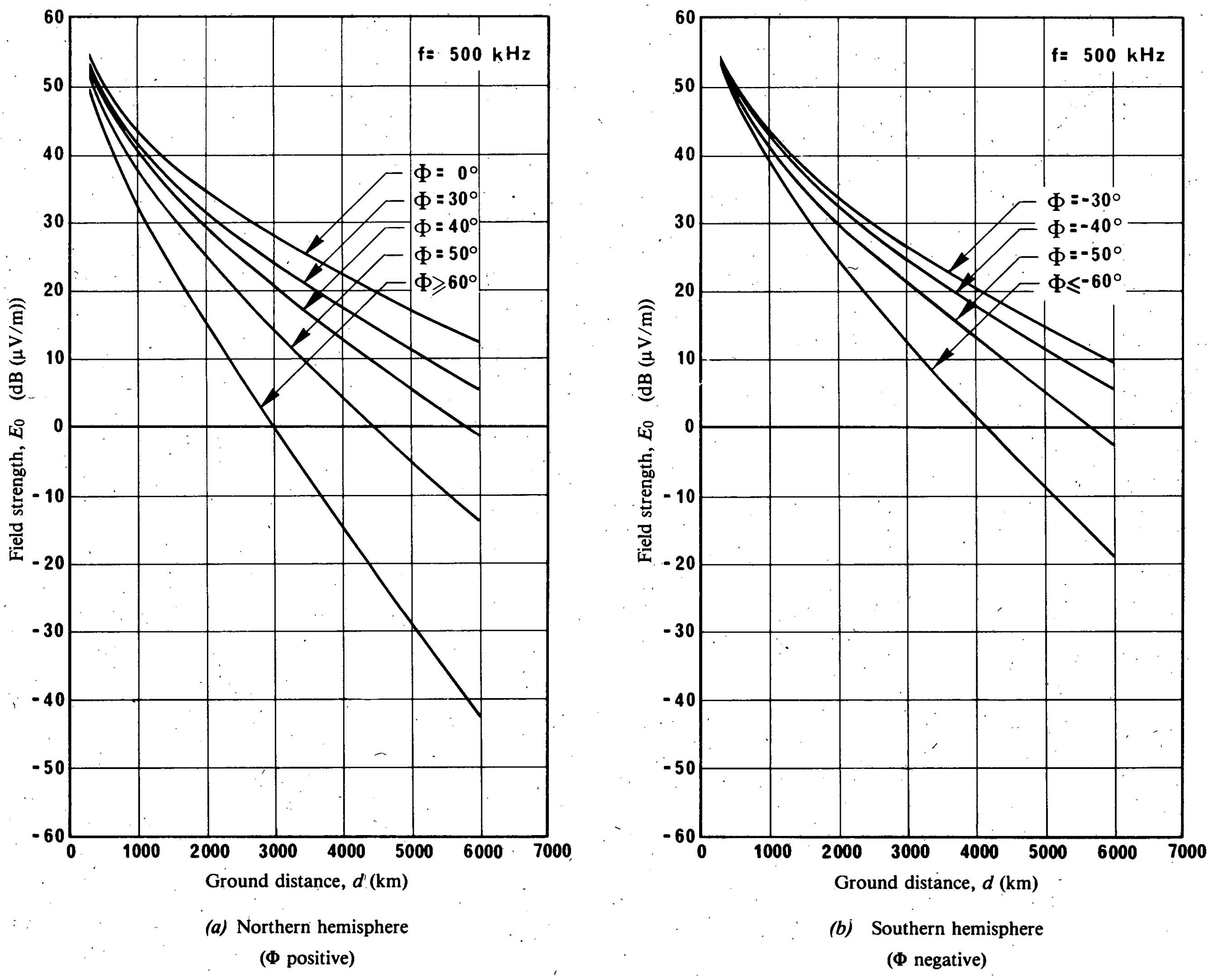


FIGURE 6 – *Curves showing E_0 for 500 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*

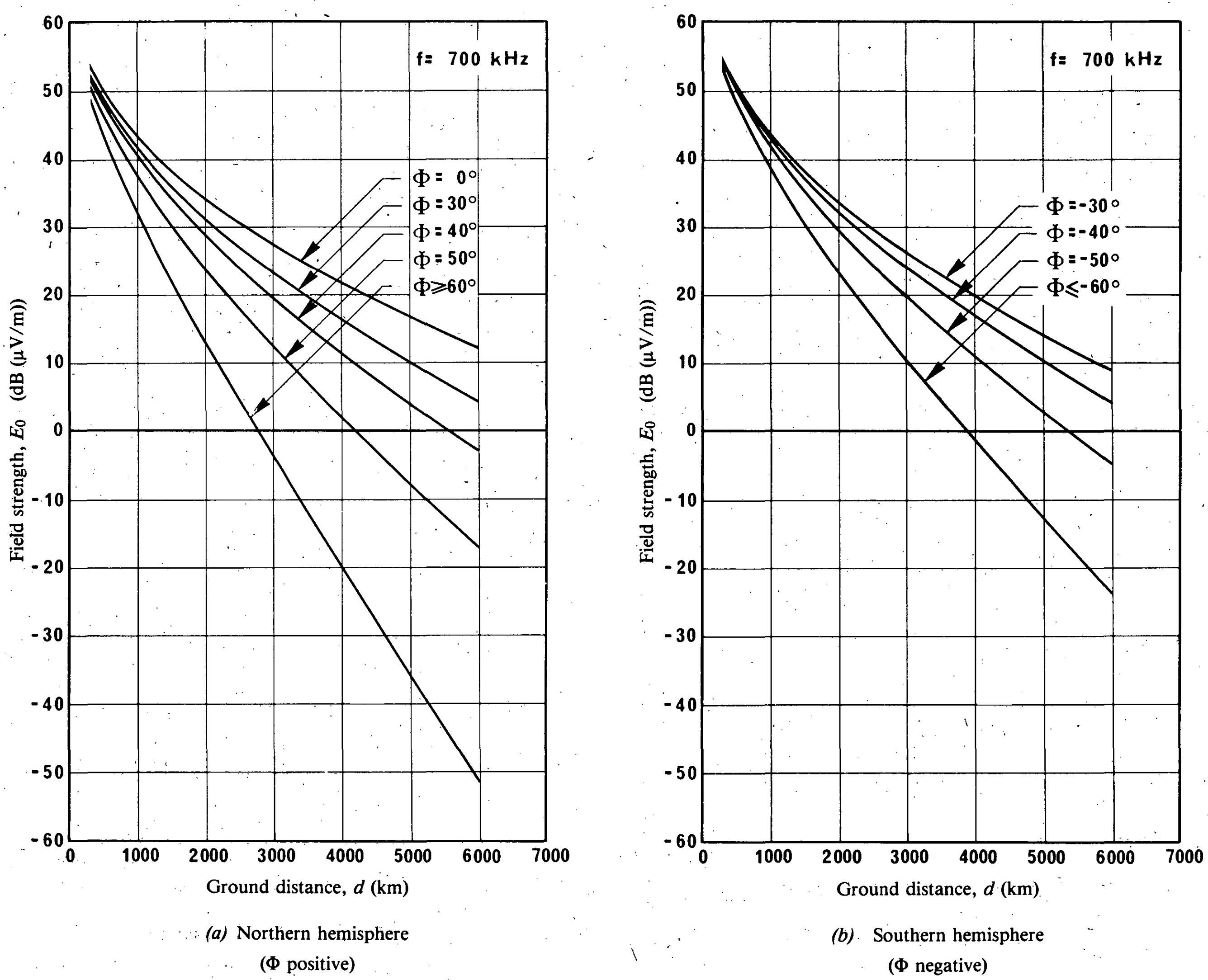


FIGURE 7 – *Curves showing E_0 for 700 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*

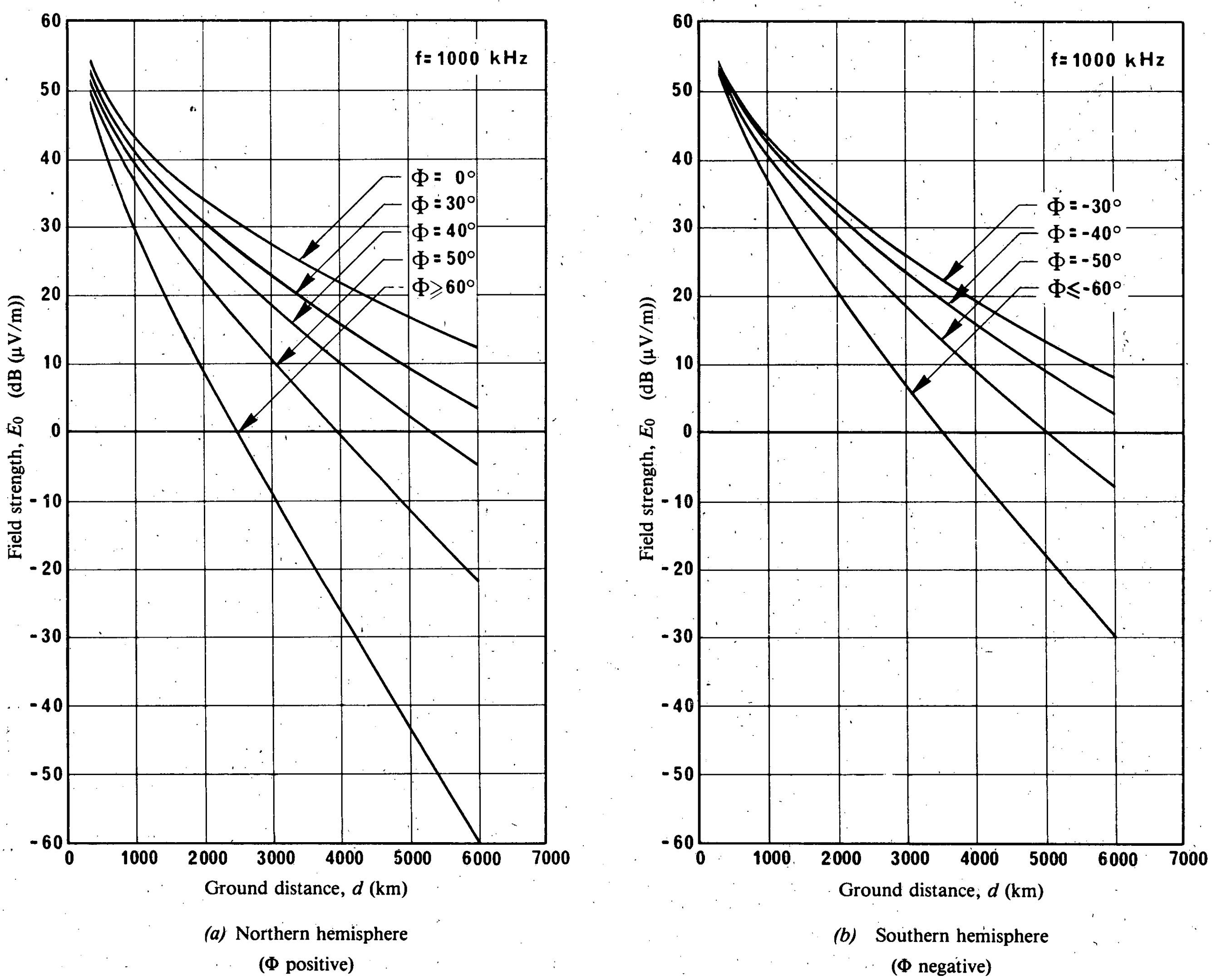
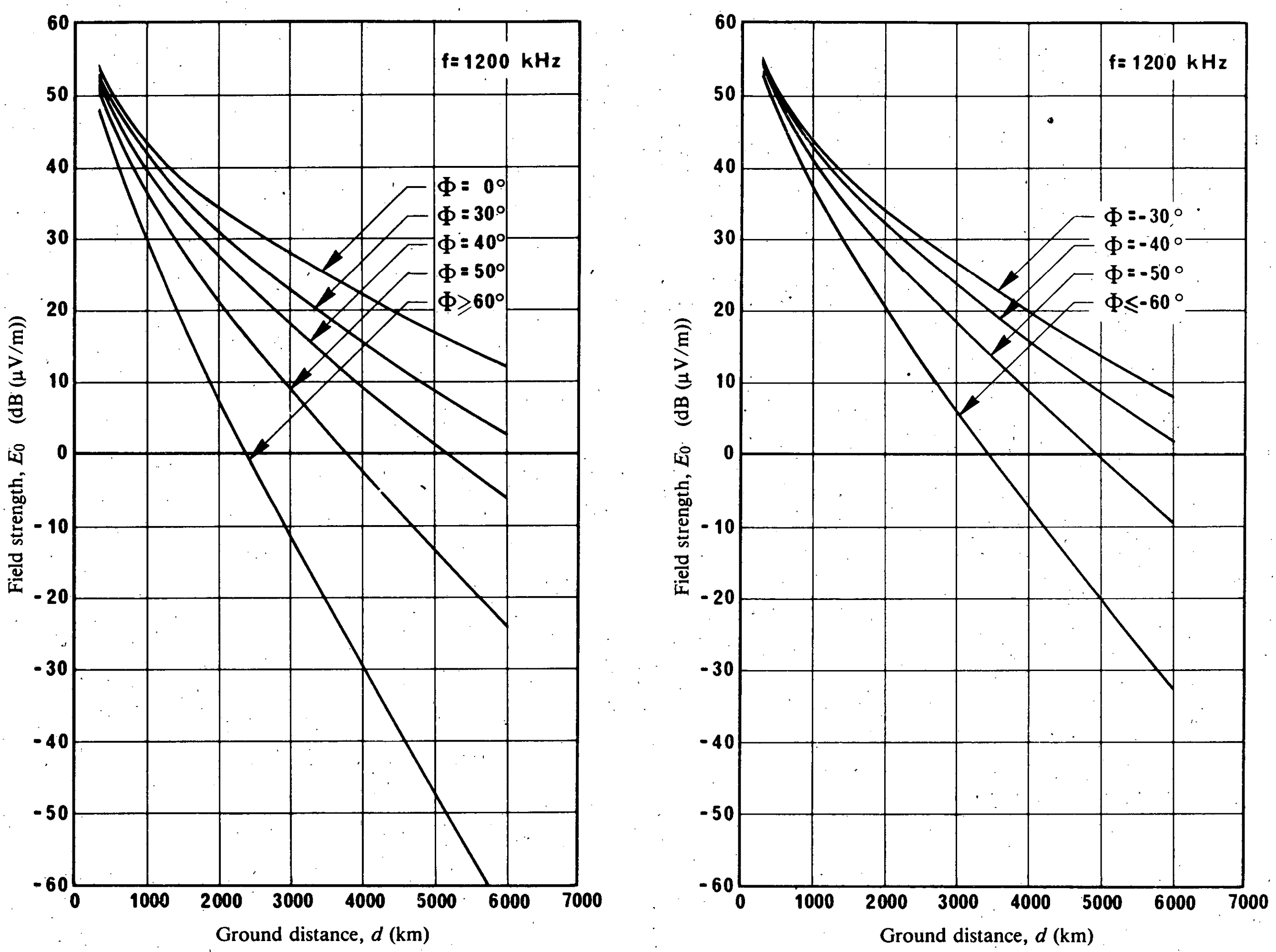


FIGURE 8 – *Curves showing E_0 for 1000 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*



(a) Northern hemisphere (Φ positive)

(b) Southern hemisphere (Φ negative)

FIGURE 9 – *Curves showing E_0 for 1200 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*

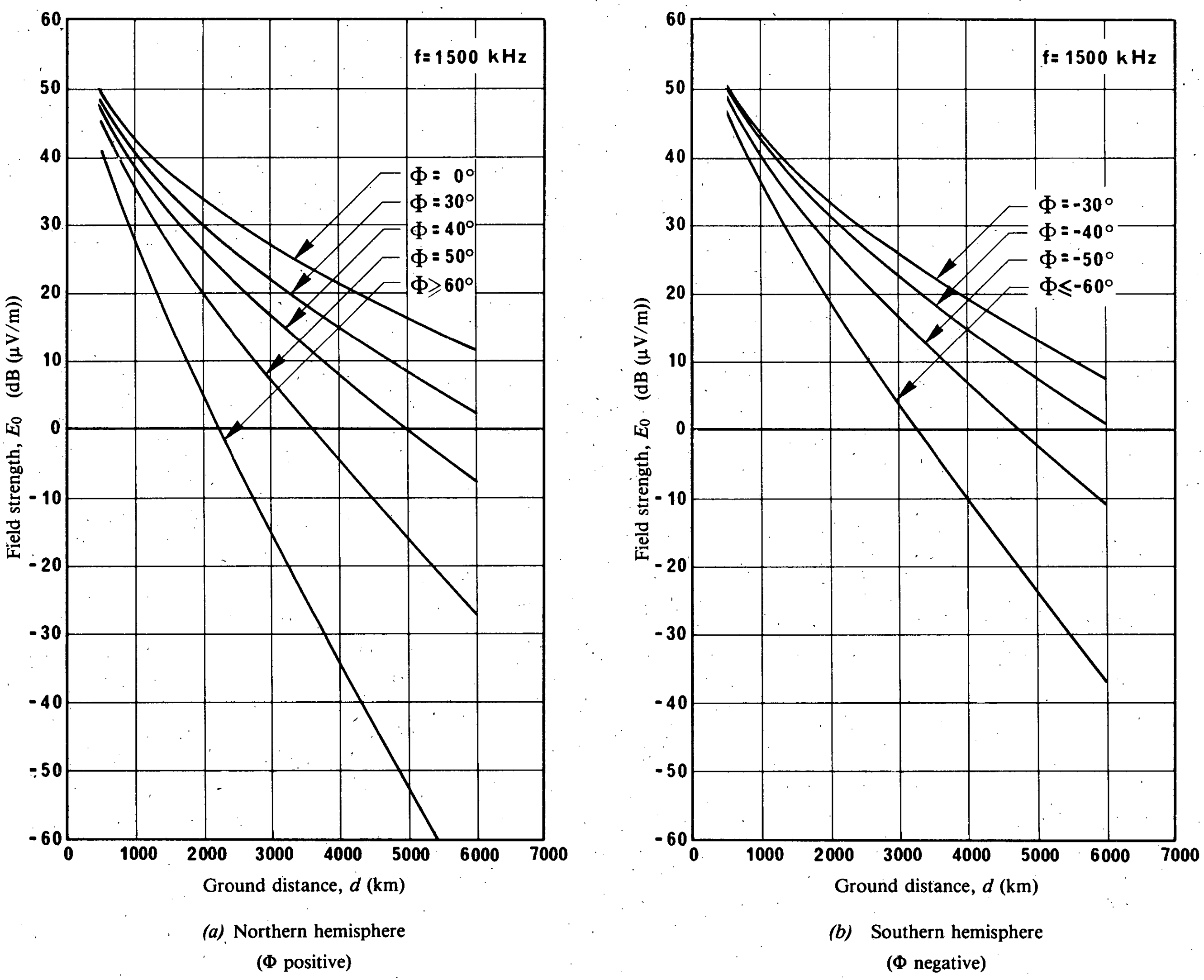


FIGURE 10 – *Curves showing E_0 for 1500 kHz, when G_S, L_p and R are all zero, for constant geomagnetic latitudes*

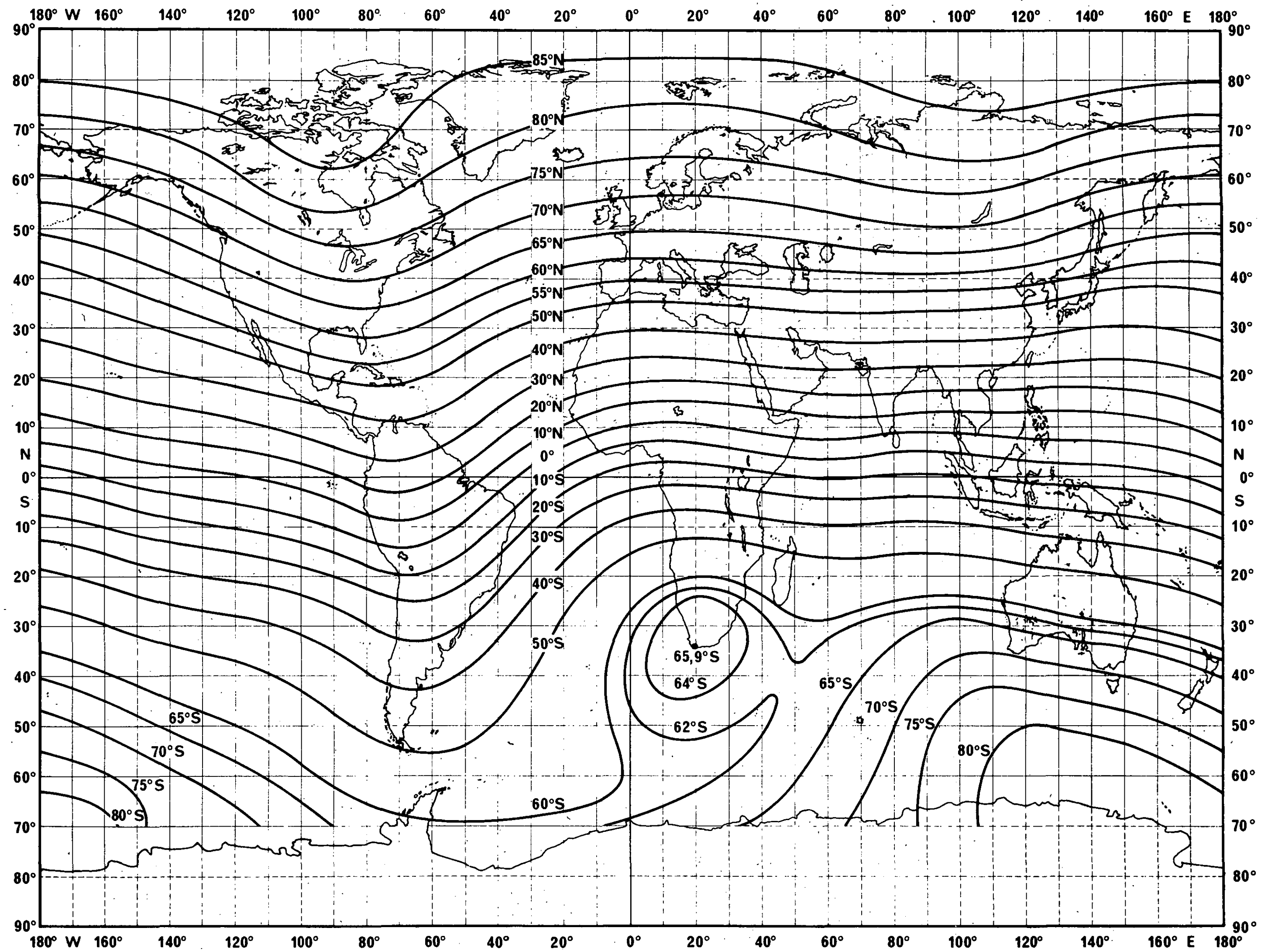


FIGURE 11 – *Map of magnetic dip (epoch 1975.0)*

(Source: Magnetic inclination or dip (epoch 1975.0) Chart No. 30 World U.S. Defense Mapping Agency Hydrographic Center)

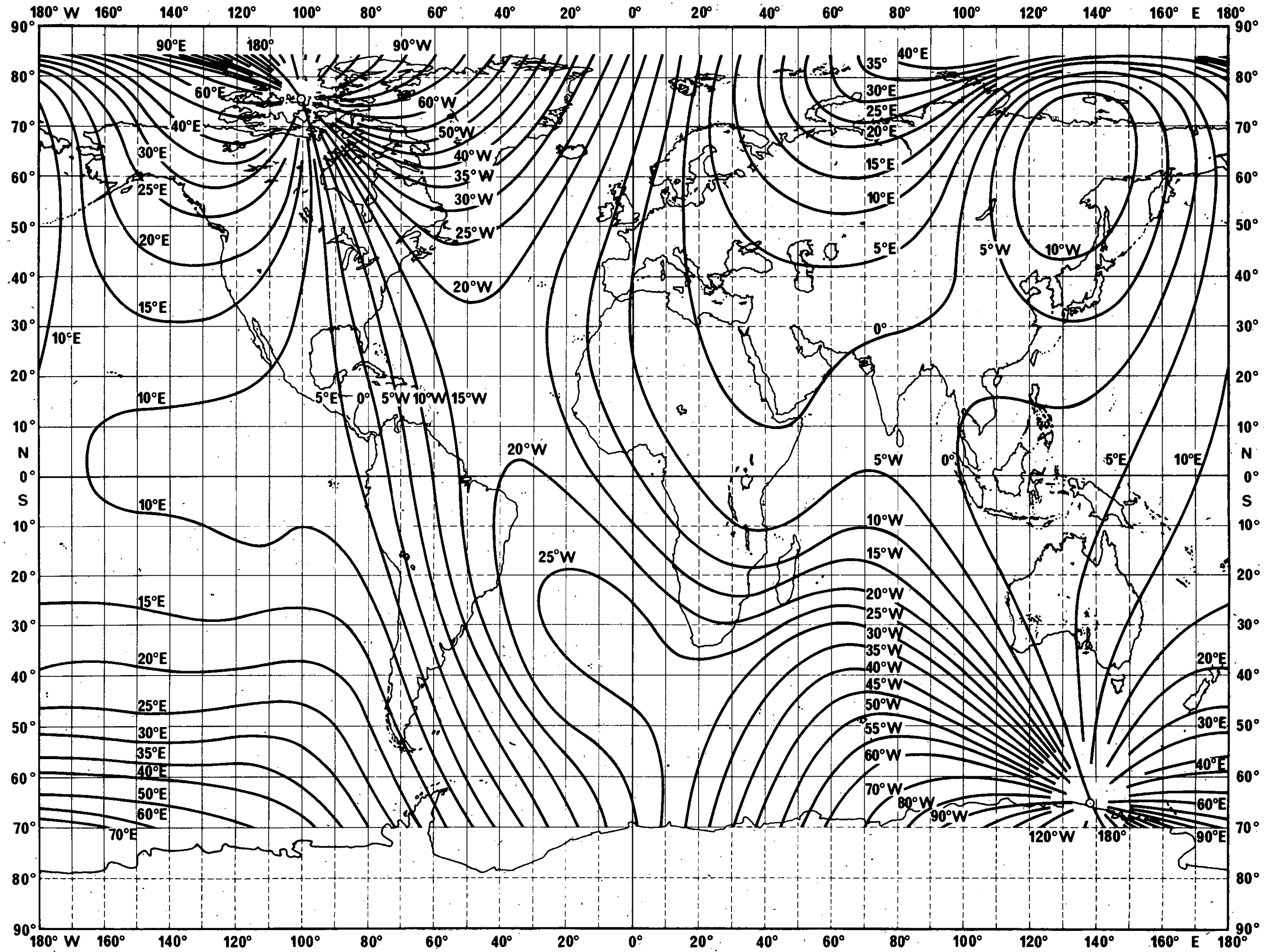


FIGURE 12 – *Map of magnetic declination (epoch 1975.0)*

(Source: Magnetic variation (epoch 1975.0) Chart No. 42, World U.S. Defense Mapping Agency Hydrographic Center)

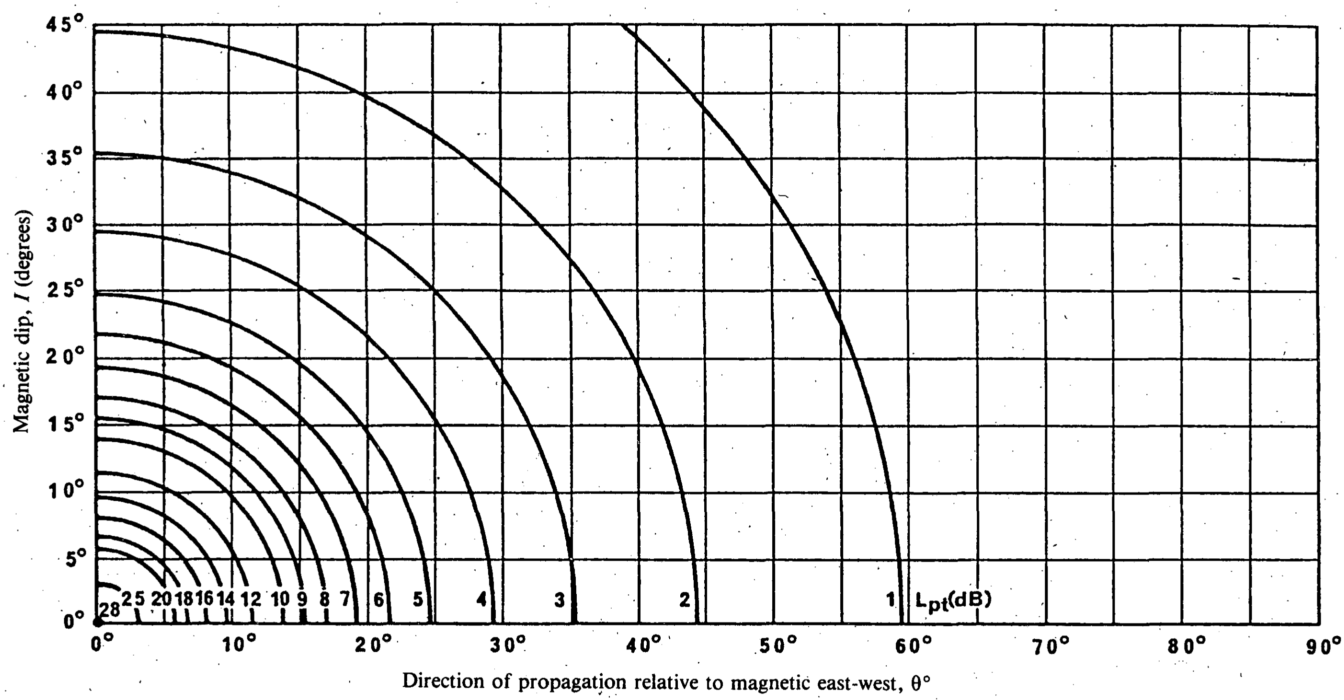


FIGURE 13 – *Excess polarization coupling loss L_p (for a single terminal)*

$$L_p = 180\,(36 + \theta^2 + I^2)^{-1/2} - 2$$

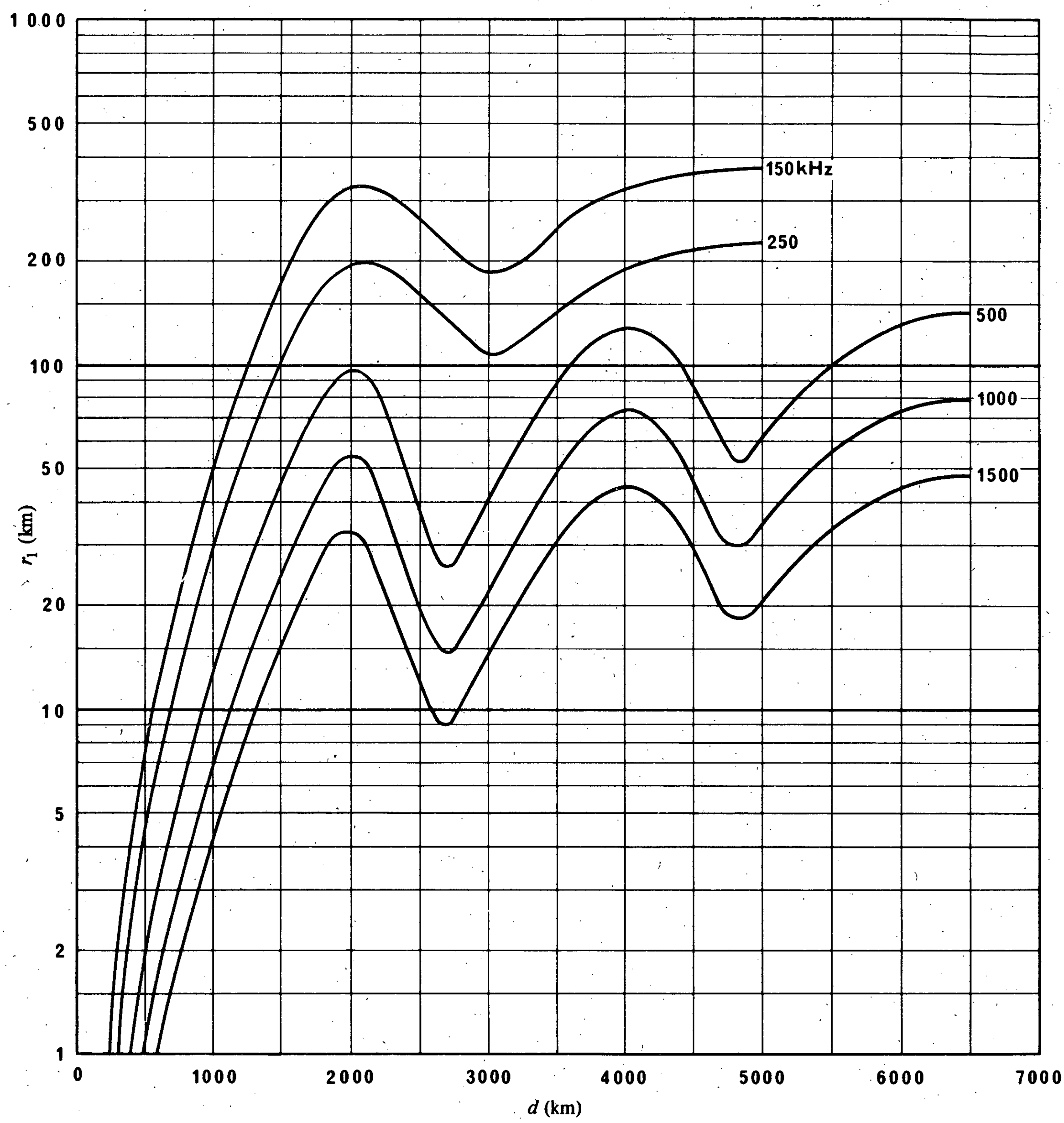


FIGURE 14a – *Values of r_1 for various frequencies*

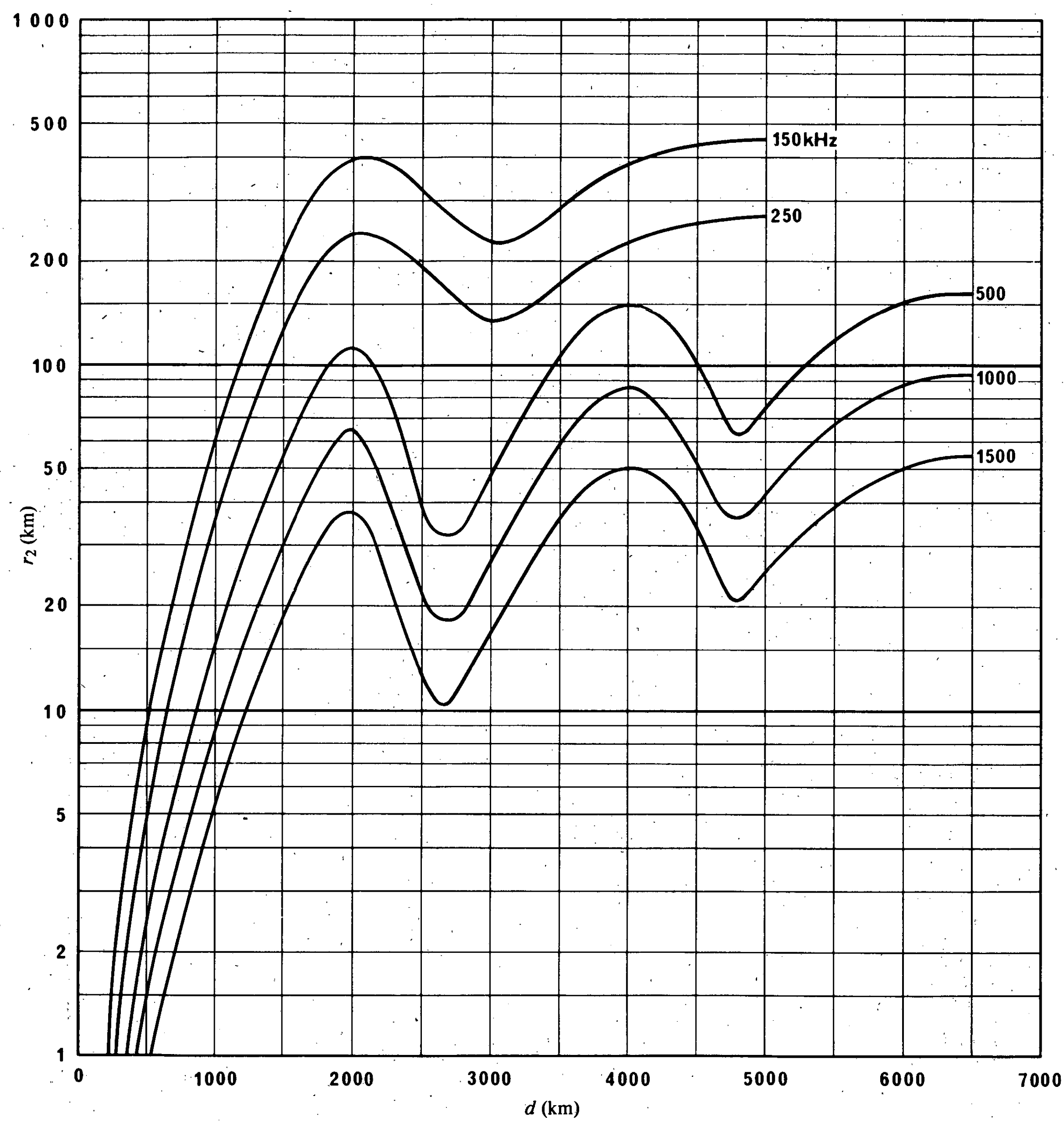


FIGURE 14b – *Values of r_2 for various frequencies*

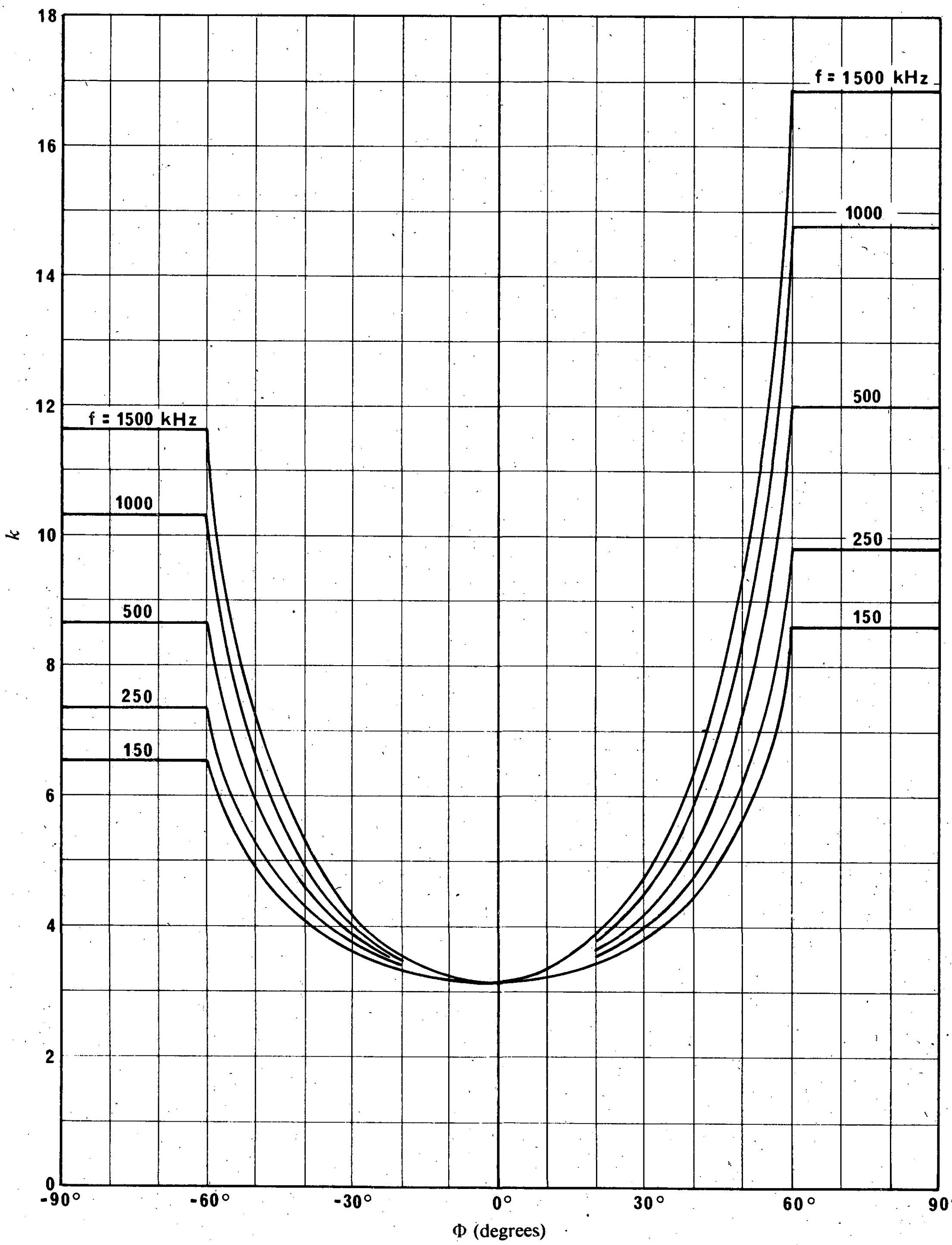


FIGURE 15 – *Basic loss factor*

$k = 3.2 + 0.19 f^{0.4} \tan^2 (\Phi + 3)$

$-60° \leqslant \Phi \leqslant 60°$

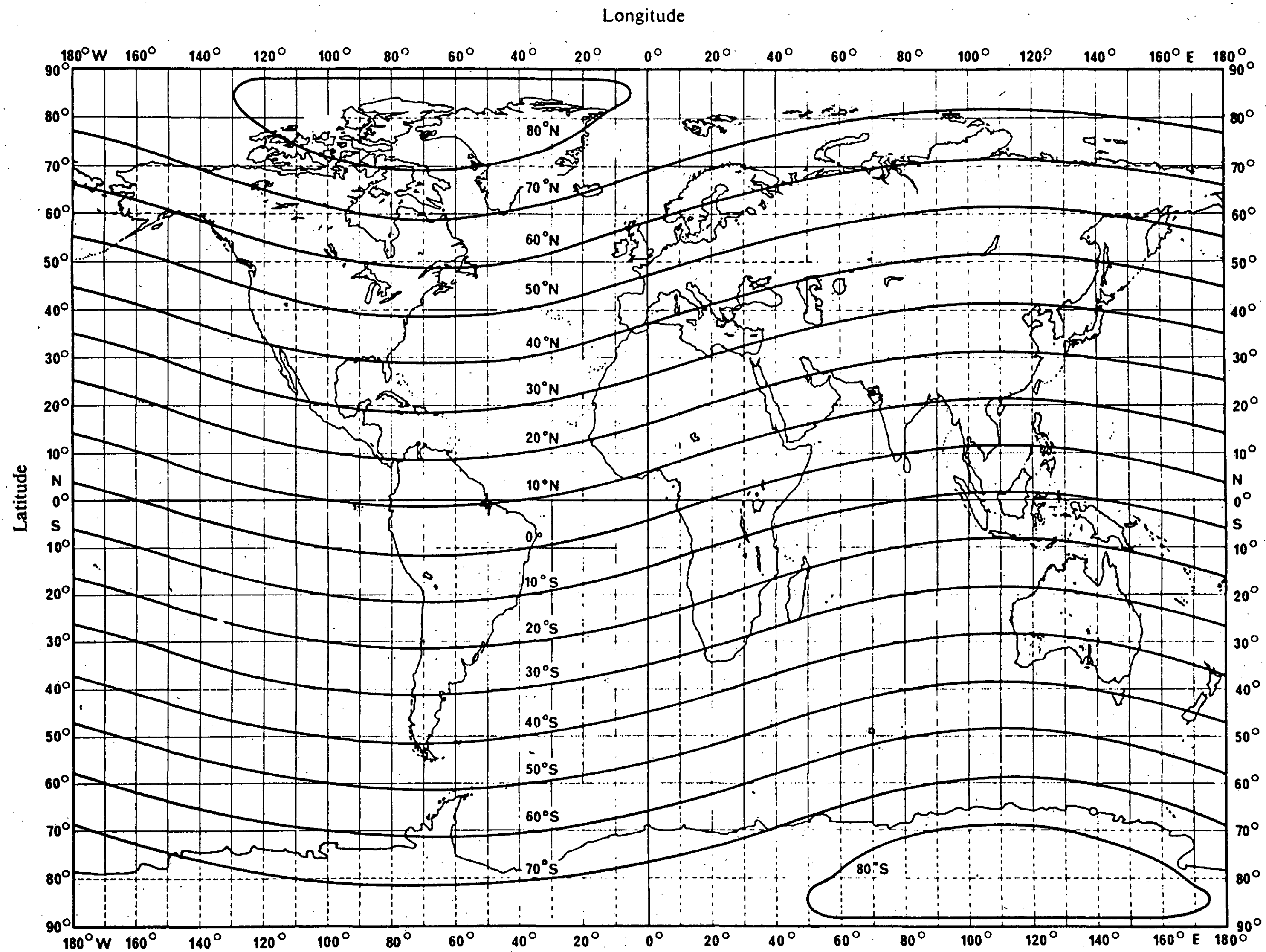


FIGURE 16 – *Geomagnetic latitudes*

$\Phi = \text{arc sin} \left[\sin \alpha \cdot \sin 78.5° + \cos \alpha \cdot \cos 78.5° \cdot \cos (69° + \beta) \right]$

Φ: geomagnetic latitude

α: geographic latitude

β: geographic longitude

North and East coordinates are considered positive, and South and West coordinates negative.

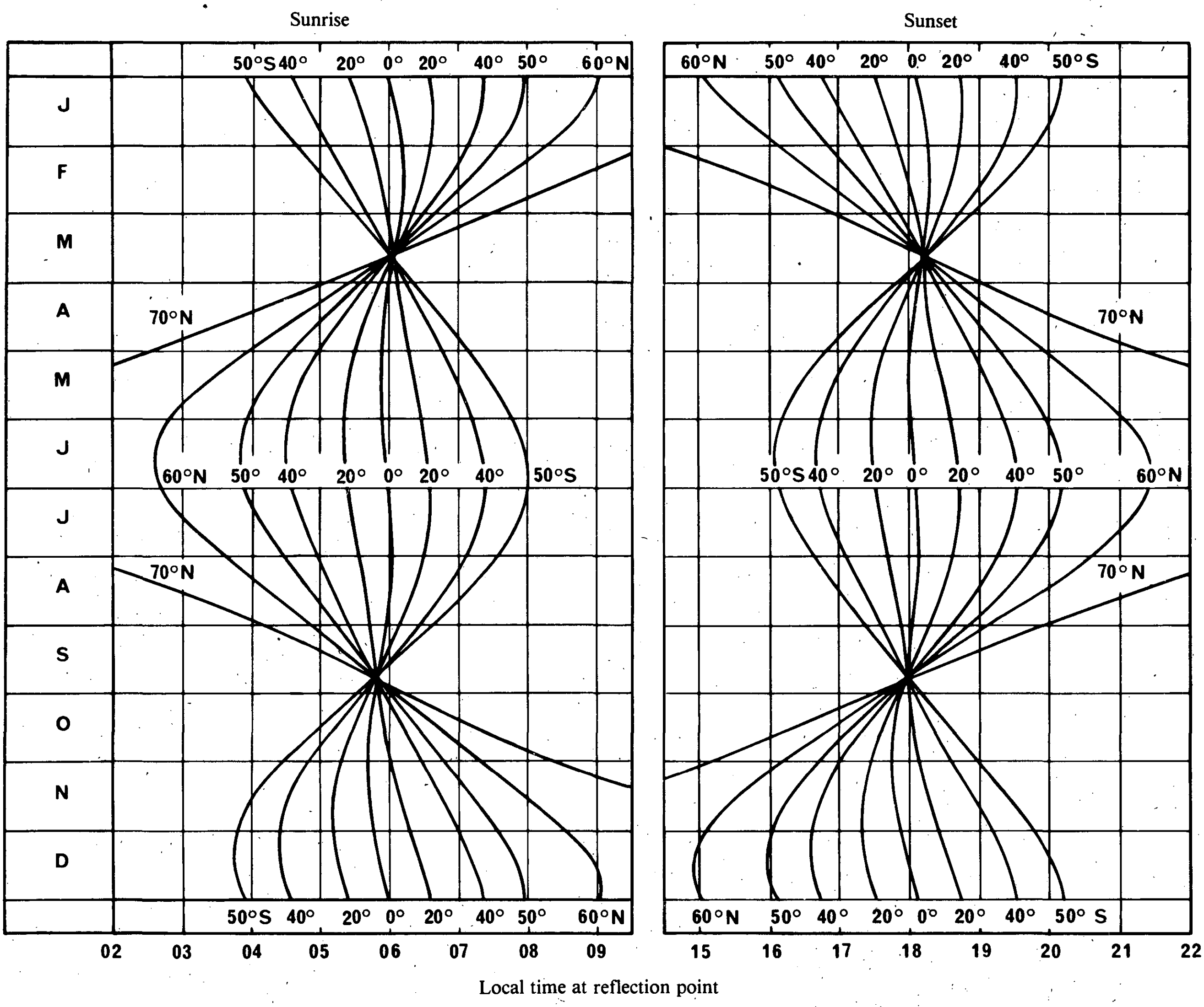


FIGURE 17 – *Times of sunrise and sunset for various months and geographical latitudes*

APPENDIX I TO ANNEX I

This Appendix contains equations that may be used in lieu of Figs. 3 and 17 for hourly loss factor, and sunset and sunrise times respectively, in the text of Annex I. For the purpose of this Appendix, the following additional symbols are used.

List of symbols

α : geographic latitude of a point on the path (degrees)

β : geographic longitude of a point on the path (degrees)

S : local mean time of sunset or sunrise at a point (hours)

North and East coordinates are considered positive, and South and West coordinates negative.

1. Hourly loss factor: L_t

These equations may be used instead of the curves in Fig. 3, within the stated limits of t. For hours between these times (i.e. near midnight) set $L_t = 0$.

L_t (sunset) $= 12.40 - 9.248\,t + 2.892\,t^2 - 0.3343\,t^3$ for $-1 < t\,(\text{sunset}) < 4$ and

L_t (sunrise) $= 9.6 + 12.2\,t + 5.62\,t^2 + 0.86\,t^3$ for $-3 < t\,(\text{sunrise}) < 1$

where t is the time in hours relative to sunset or sunrise at the path mid-point.

2. Sunset and sunrise times

For non-polar locations, i.e. such that $|\alpha| < 65°$, the times of sunset and sunrise can be calculated as follows, to an accuracy of $\pm$ 2 min.

N: day of year, in days; e.g. 1 January = 1;

S': approximate local time of event, e.g. sunset = 1800 h, sunrise = 0600 h;

Z: Sun's zenith distance (degrees) = 90.8333° (90° 50′) for sunset or sunrise.

Step 1: Calculate observer's longitude, B:

$$B = \beta/15 \qquad \text{h}$$

Step 2: Calculate the time of event, Y:

$$Y = N + (S' - B)/24 \qquad \text{days}$$

Step 3: Calculate Sun's mean anomaly, M:

$$M = 0.985600\,Y - 3.289 \qquad \text{degrees}$$

Step 4: Calculate Sun's longitude, L:

$$L = M + 1.916 \sin M + 0.020 \sin 2M + 282.634 \qquad \text{degrees}$$

Note in which quadrant L occurs.

Step 5: Calculate sun's right ascension, RA:

$$\tan RA = 0.91746 \tan L$$

Note that RA must be in the same quadrant as L.

Step 6: Calculate Sun's declination s:

s: Sun's declination, given by:

$\sin s = 0.39782 \sin L$, from which:

$$\cos s = +\sqrt{1 - \sin^2 s}$$

Note that $\sin s$ may be positive or negative but $\cos s$ must always be positive.

Step 7: Calculate Sun's local hour angle H:

H: Sun's local hour angle, given by:

$$\cos H = x = (\cos Z - \sin s \cdot \sin \alpha)/(\cos s \cdot \cos \alpha)$$

Note that if $|x| > 1$, there is no sunset or sunrise.

From $\cos H$, obtain H in degrees; for sunrise $180 < H < 360$; for sunset $0 < H < 180$.

Step 8: Calculate local mean time of event, S:

$$S = H/15 + RA/15 - 0.065710\,Y - 6.622$$

Note that S is expressed in hours and that multiples of 24 should be added or subtracted until $0 < S < 24$.

Note that S is the local time at the point concerned. The corresponding standard time is $S - B + \beta_m/15$ h where β_m is the longitude of the standard meridian for the desired time zone (degrees) so that, for example, universal time = $S - B$.

RECOMMENDATION 683*

SKY-WAVE FIELD STRENGTH PREDICTION METHOD FOR PROPAGATION TO AIRCRAFT AT ABOUT 500 kHz

(Study Programme 31D/6)

(1990)

The CCIR,

CONSIDERING

(a) that Question 53-2/8, which concerns the use of frequencies by the maritime mobile service, in the bands 435-526.5 kHz, asks *inter alia* what are the sharing criteria with other services, taking into consideration the propagation mechanisms for a receiving antenna located well above the ground level;

(b) that a method for sky-wave field strength prediction for receivers close to the ground is given in Recommendation 435; and that information on the accuracy of that method is given in § 6 of Annex I of that Recommendation,

UNANIMOUSLY RECOMMENDS

that the method described in Annex I should be used for the prediction of sky-wave field strength at about 500 kHz in the vicinity of high flying aircraft.

ANNEX I

1. Introduction

This method of prediction gives the night-time sky-wave field strength at the position occupied by an aircraft when a given power is radiated from a short vertical antenna at 500 kHz. It applies for paths up to 4000 km and should be used with caution for geomagnetic latitudes greater than 60°.

The sky-wave field at the aircraft will in general be elliptically polarized. Aircraft antennas may respond differently to vertical and horizontal fields, and the combined effect of these fields may depend on the size of the aircraft and on its heading relative to the direction of arrival of the sky wave. Additionally, the down-coming sky wave will be reflected by the ground and the field at the aircraft will thus depend also on the reflection coefficient and angle of arrival of the down-coming wave. Furthermore, the location of the reflection point will change rapidly as the aircraft moves. Additionally, there may be significant differences between predicted field strengths and measured data for low angles of arrival.

The prediction method therefore gives only the maximum vertical and horizontal field components which would be measured in the vicinity of the aircraft after taking local ground reflections into account.

Formulae for the strength of the down-coming sky wave are given in § 2 and formulae for the maximum values of the vertical and horizontal electric field components in the vicinity of the aircraft are given in § 3.

* This Recommendation is brought to the attention of Study Group 8.

2. Field strength of down-coming sky wave

The down-coming sky wave is in general elliptically polarized. The power flux-density of the down-coming wave can be represented by an equivalent field strength given by:

$$E_D = V + G_S + G_0 - L_{pt} + A_0 - 20 \log p - 10^{-3} k_R p - L_t \tag{1}$$

where:

E_D : annual median of half-hourly median field strengths (dB(μV/m)) for a given transmitter cymomotive force, V, and at a given time, t, relative to sunset or sunrise as appropriate, for the down-coming wave,

V : transmitter cymomotive force, dB above a reference cymomotive force of 300 V (see § 2.2),

G_S : sea-gain correction at the transmitter (dB) (see § 2.3),

G_0 : a parameter given in Fig. 1 as a function of d (dB),

L_{pt} : excess polarization-coupling loss at the transmitter (dB) (see § 2.4),

A_0 = 101.6 − 2 sin Φ, where Φ is defined by equation (12),

p : slant-propagation distance (km) (see § 2.5),

k_R : loss factor incorporating effects of ionospheric absorption, focusing and terminal losses, and losses between hops on multi-hop paths (see § 2.6),

L_t : hourly loss factor (dB) (see § 2.7).

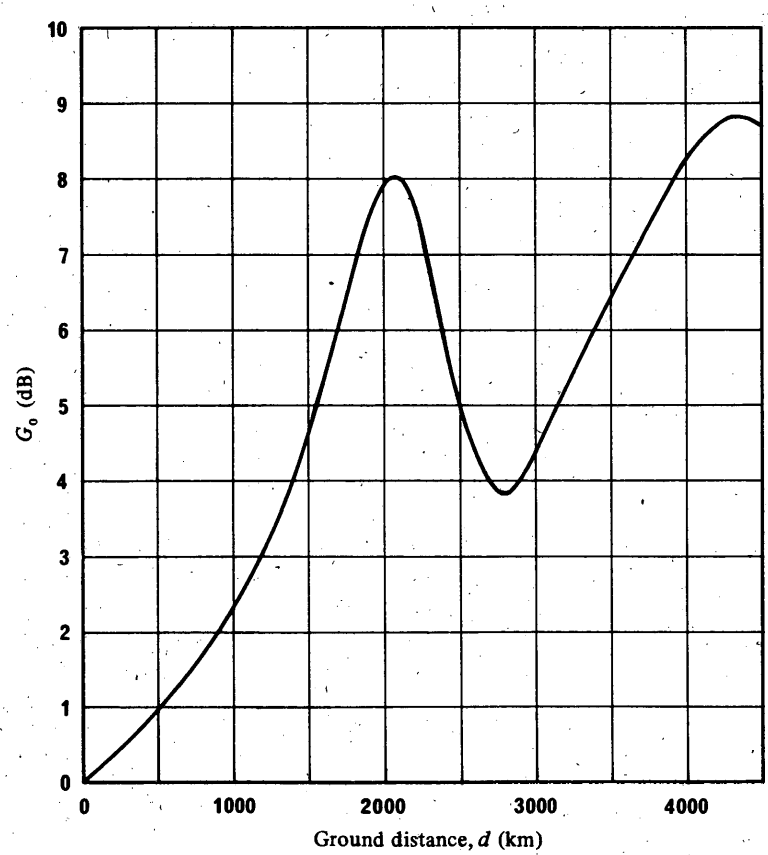


FIGURE 1 – *Sea gain (G_0) for a transmitter on the coast*

Note. – This curve is not the same as curve A of Fig. 2 of Recommendation 435, as it applies to 500 kHz.

2.1 *Reference time*

The reference time is taken as six hours after the time at which the Sun sets at a point S on the surface of the Earth. For paths shorter than 2000 km, S is the mid-point of the path. On longer paths, S is 750 km from the terminal where the sun sets last, measured along the great-circle path.

2.2 *Cymomotive force*

The cymomotive force V is given as:

$$V = P + 20 \log (d/p) \tag{2}$$

where:

P: radiated power (dB(1 kW)),

d: ground distance (km),

p: slant-propagation distance (km).

For paths longer than 1000 km, V is approximately equal to P.

Note. – the reference cymomotive force of 0 dB (300V) corresponds to an e.m.r.p. of 1 kW.

2.3 *Sea gain*

G_S is the additional signal gain when the transmitter is situated near the sea, but it does not apply to propagation over fresh water. G_S is given by:

$$G_S = G_0 - c_1 - c_2 \qquad \text{for} \qquad (c_1 + c_2) < G_0 \tag{3}$$

$$G_S = 0 \qquad \text{for} \qquad (c_1 + c_2) \geqslant G_0 \tag{4}$$

where:

G_0: gain when the transmitter is on the coast and the sea is unobstructed by further land,

c_1: correction to take account of the distance between the transmitter and the sea,

c_2: correction to take account of the width of one or more sea channels, or the presence of islands.

G_0 is given in Fig. 1 as a function of d.

The correction c_1 is given by

$$c_1 = \frac{s_1}{r_1} G_0 \tag{5}$$

where:

s_1: distance of transmitter from sea, measured along great-circle path (km),

$r_1 = 1.4\ G_0^2$ (km).

The correction c_2 is given by:

$$c_2 = \alpha\, G_0 \left(1 - \frac{s_2}{r_2}\right) \qquad \text{for} \quad s_2 < r_2 \tag{6}$$

$$c_2 = 0 \qquad \text{for} \quad s_2 \geqslant r_2 \tag{7}$$

where:

s_2: distance of transmitter from next section of land, measured along great-circle path (km),

$r_2 = 1.7\ G_0^2$ (km),

α: proportion of land in the section of path between r_2 and s_2 ($0 < \alpha \leqslant 1$).

If a computer is used but a terrain data bank is not available to calculate α, then α should be made equal to 0.5, which implies that land and sea are present in equal proportions in the section of path between r_2 and s_2.

To facilitate calculation, Fig. 2 shows r_1, the greatest distance from the sea for which sea gain has to be calculated, and also shows r_2, the greatest distance to the next section of land for which the correction c_2 is required.

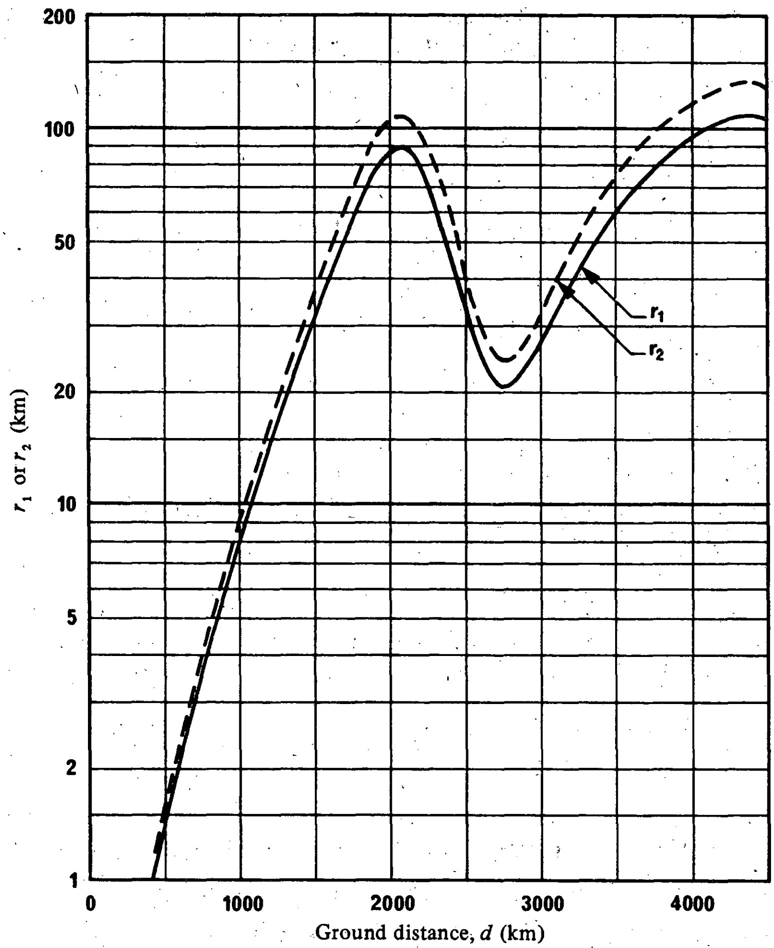


FIGURE 2 – *Values of r_1 and r_2*

2.4 *Polarization coupling loss at transmitter, L_{pt}*

L_{pt} is the excess polarization coupling loss, given by one of the following two formulae:

$$L_{pt} = 180\ (36 + \theta^2 + I^2)^{-1/2} - 2 \quad \text{dB} \quad \text{if } I \leqslant 45°$$

$$L_{pt} = 0 \quad \text{if } I > 45° \tag{8}$$

where I is the magnetic dip, North or South, in degrees at the transmitter and θ is the path azimuth measured in degrees from the magnetic East-West direction, such that $|\theta| \leqslant 90°$. The most accurate available values of magnetic dip and declination (e.g. see Figs. 11 and 12 of Recommendation 435) should be used in determining θ and I.

Figure 3 shows values of L_{pt} calculated from equation (8).

2.5 *Slant propagation distance*

For paths longer than 1000 km, p is approximately equal to the ground distance d (km). For shorter paths

$$p = (d^2 + 40\ 000)^{1/2} \tag{9}$$

Equation (9) may be used for paths of any length with negligible error. It should be used in all cases where the distances considered are both above and below 1000 km, to avoid discontinuities in field strength as a function of distance.

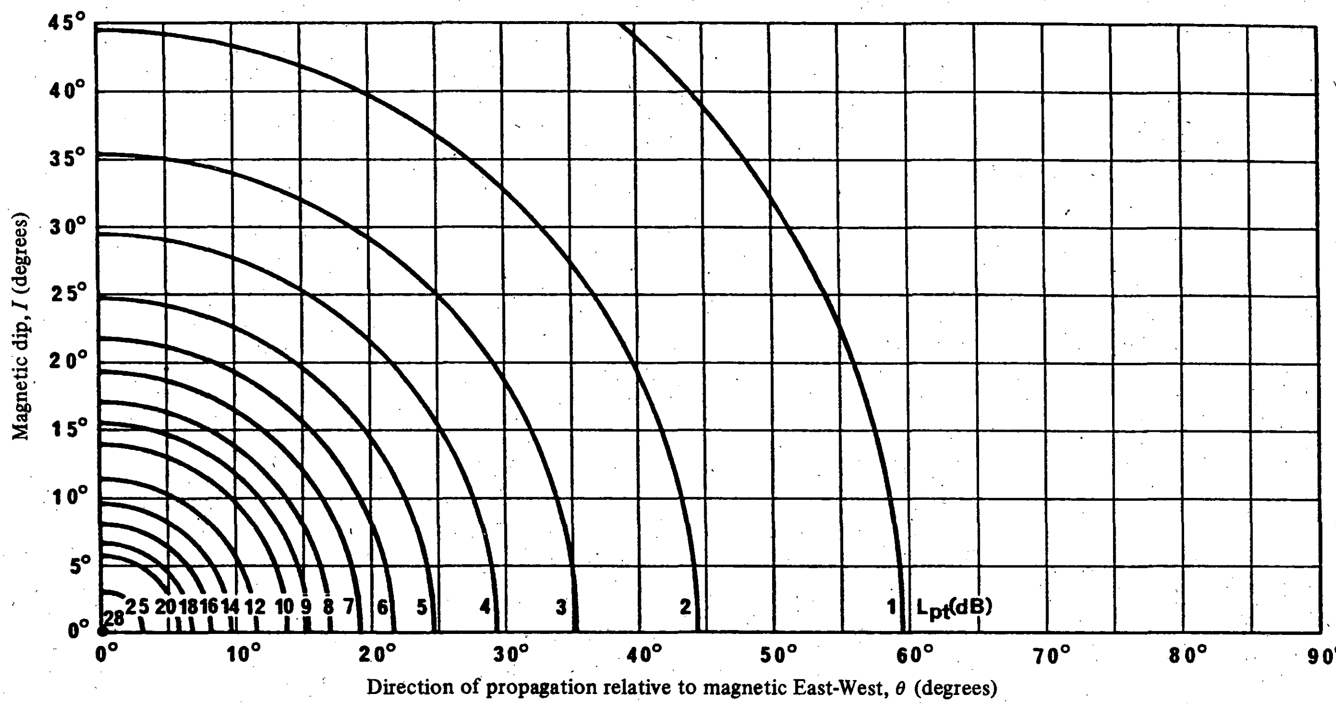


FIGURE 3 – *Excess polarization coupling loss* L_{pt}

$$L_{pt} = 180\,(36 + \theta^2 + I^2)^{-1/2} - 2$$

2.6 *Loss factor*

The loss factor k_R is given by

$$k_R = k + 10^{-2}\, bR \tag{10}$$

where:

R: twelve-month smoothed International Relative Sunspot Number and

$b = 4$ for North American paths,

$b = 1$ for Europe and Australia and

$b = 0$ elsewhere.

The basic loss factor k is given by:

$$k = 3.2 + 2.28 \tan^2(\Phi + 3) \tag{11}$$

If $\Phi > 60°$, equation (11) is evaluated for $\Phi = 60°$. If $\Phi < -60°$, equation (11) is evaluated for $\Phi = -60°$. Figure 15 of Recommendation 435 (curve for 500 kHz) shows values of k calculated from equation (11) according to these rules.

For paths shorter than 3000 km:

$$\Phi = 0.5\,(\Phi_T + \Phi_R) \tag{12}$$

where Φ_T and Φ_R are the geomagnetic latitudes at the transmitter and receiver respectively, determined by assuming an Earth-centred dipole field model with northern pole at 78.5° N, 69° W geographic co-ordinates. Φ_T and Φ_R are taken as positive in the northern hemisphere and negative in the southern hemisphere (see Fig. 16 of Recommendation 435). Paths longer than 3000 km are divided into two equal sections which are considered separately. The value of Φ for each half-path is derived by taking the average of the geomagnetic latitudes at one terminal and at the mid-point of the whole path, the geomagnetic latitude at the mid-point of the whole path being assumed to be the average of Φ_T and Φ_R. As a consequence:

$$\Phi = (3\Phi_T + \Phi_R)/4 \text{ for the first half of the path and} \qquad (13)$$

$$\Phi = (\Phi_T + 3\Phi_R)/4 \text{ for the second half.} \qquad (14)$$

The values of k calculated from equation (11) for the two half-paths are then averaged and used in equation (10).

2.7 *Hourly loss factor*

The hourly loss factor, L_t, is given in Fig. 3 of Recommendation 435 which shows the average of the annual median hourly variations for Europe and Australia, derived from Figs. 2 and 6 of Report 431 respectively. The time, t, is the time in hours relative to the sunrise or sunset reference times as appropriate. These are taken at the ground at the mid-path position for $d < 2000$ km and at 750 km from the terminal where the Sun sets last or rises first for longer paths.

Figure 17 of Recommendation 435 shows sunset and sunrise times for a range of geographic latitudes.

3. Field strength in the vicinity of the aircraft

The down-coming sky wave will be reflected by the ground and the resultant field strength in the vicinity of the aircraft will be the vector sum of the down-coming sky wave and the ground reflected wave. The field strength will be greatest when the two waves add in phase. The resultant field strength is assumed to be 6 dB greater than that of the down-coming wave because in-phase addition is always possible.

The resultant electric field may be resolved into a transverse horizontal component E_{HT} and a component which lies in the vertical plane. The latter component, which is not itself vertical, can in turn be resolved into a vertical component E_V and a longitudinal horizontal component E_{HL}.

It should be noted that the total field may also contain a ground wave: e.g. for aircraft flying at a height of about 11 km, the ground wave is receivable to distances up to 400 km. However, no account is taken of the ground wave in this prediction method.

3.1 *Vertical component*

The maximum vertical electric field strength E_V at the aircraft is given by:

$$E_V = E_D - L_{pv} + 5 + 20 \log (d/p) \qquad (15)$$

where:

L_{pv}: excess polarization coupling loss at receiver, for vertical polarization.

L_{pv} is given by equation (8) by writing L_{pv} in place of L_{pt}. The values of θ and I which apply at the position of the aircraft should be used.

3.2 *Transverse horizontal component*

The maximum transverse horizontal electric field strength E_{HT} at the aircraft is given by:

$$E_{HT} = E_D - L_{ph} + 6 \qquad (16)$$

where:

L_{ph}: excess polarization coupling loss for horizontal polarization.

L_{ph} is given by Fig. 4. Values derived from Fig. 4 for temperate latitudes should be used with caution for paths shorter than 500 km.

3.3 *Longitudinal horizontal component*

The maximum longitudinal horizontal electric field strength E_{HL} at the aircraft is given by:

$$E_{HL} = E_D - L_{pv} + 51 - 20 \log p \qquad (17)$$

E_{HL} can be disregarded for paths longer than 1000 km.

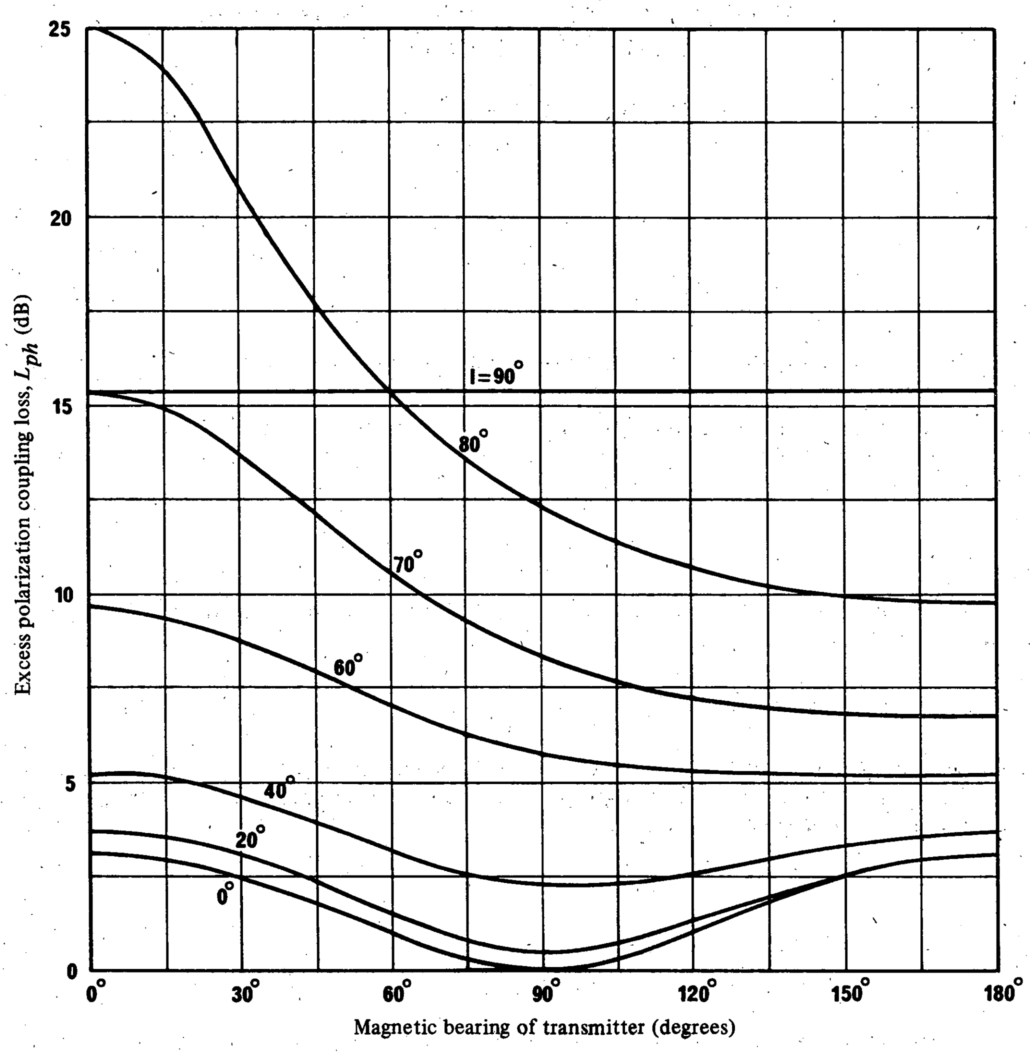


FIGURE 4 – *Excess polarization coupling loss L_{ph} for horizontal polarization*

I: magnetic dip angle, North or South (degrees)

Note. – If the aircraft is North of the magnetic dip equator, the magnetic bearing of the transmitter is measured from magnetic North. If the aircraft is South of the dip equator, the bearing is measured from magnetic South.

4. Field-strength variation

The field strength exceeded for 10% of the total time on a series of nights at a given season, during short periods centred on a specific time, is 8 dB greater than the value of E_D given in § 2. Larger values may be observed at the peak of the solar cycle.

At night, 500 kHz sky waves propagating in temperate latitudes are strongest in spring and autumn and are weakest in summer and winter, the summer minimum being the more pronounced. The overall variation may be as much as 15 dB. The seasonal variation is much smaller in tropical latitudes.

5. Day-time field strength

In Europe the median day-time field strength in winter is 25 dB less than the night-time value of E_D given in § 2. In summer the day-time field strength is about 60 dB less than E_D.

In spring and autumn in Europe, day-time field strengths have values between the summer and winter values.

RECOMMENDATION 684

PREDICTION OF FIELD STRENGTH AT FREQUENCIES BELOW ABOUT 500 kHz

(Study Programme 31D/6)

(1990)

The CCIR,

CONSIDERING

(a) that there is a need to give guidance to engineers for the planning of radio services in the frequency band below about 500 kHz;

(b) that methods developed for the estimation of field strength at frequencies below about 500 kHz are described in Reports 265 and 895, while, on the other hand, different methods which have been developed for the frequency band 150-1705 kHz are described in Report 575,

RECOGNIZING

that the methods contained in these Reports still need to be verified on a world-wide basis, since they have been largely based on observations in ITU Region 1,

UNANIMOUSLY RECOMMENDS

that the methods of Report 265 (the wave-hop method) and of Report 895 (the waveguide-mode method) be adopted for use in the estimation of field strength at frequencies below about 500 kHz, keeping in mind some of the limitations highlighted in Annex I.

ANNEX I

APPLICATION OF THE METHODS OF FIELD-STRENGTH PREDICTION AT FREQUENCIES BELOW 500 kHz

The waveguide-mode method described in Report 895 shall be used to predict field strengths at frequencies up to about 60 kHz, using the value 0.3/74 for the ionospheric parameter β/H' for daytime paths, until additional results taking into account the variations with location, season, solar activity and frequency can be obtained. A more detailed model, which is a function of frequency and latitude, is given in the Report for night-time paths.

Since the lower boundary of the waveguide is the Earth, a ground conductivity map of the world (e.g. Report 717) needs to be a part of any programme developed for global application. The ground conductivity map currently used for VLF and LF is one that is largely based on geological information.

The wave-hop method of Report 265 shall be used at frequencies between about 60 and 500 kHz. The results of this method are in good agreement with those of Recommendation 435 in the overlapping frequency band.

When using this method, account needs to be taken of ground-wave propagation (Recommendation 368), and due allowance taken of the vertical plane antenna factor, using the information in Reports 265 and 575.

SECTION 6E: IONOSPHERIC PROPAGATION PREDICTION AT FREQUENCIES BETWEEN ABOUT 1.6 AND 30 MHz

RECOMMENDATION 371-6

CHOICE OF INDICES FOR LONG-TERM IONOSPHERIC PREDICTIONS

(Question 34/6)

(1963-1970-1974-1978-1982-1986-1990)

The CCIR,

UNANIMOUSLY RECOMMENDS

1. that the 12-month running mean sunspot number R_{12} be adopted as the index to be used for all ionospheric predictions for dates more than twelve months ahead of the date of the last observed value of R_{12};

2. that R_{12}, or the 12-month running mean value of the indices *IG*, or Φ, be adopted as the index to be used for predicting monthly median values of foF2 and M(3000)F2 for dates certainly up to six, and perhaps up to twelve months ahead of the date of the last observed values: substantially equivalent results should be obtainable by the use of any of these indices;

3. that Φ_{12} be adopted as the index to be used for predicting monthly median values of foE and foF1 for dates certainly up to six, and perhaps up to twelve months ahead of the date of the last observed value;

4. that caution be shown in the use of the recommended indices at high magnetic latitudes, where the resulting ionospheric predictions may not be sufficiently accurate.

ANNEX I

1. Introduction

The concept of indices for long-term ionospheric predictions relies on the assumption that the important characteristics of the ionosphere, such as the critical frequencies of the various layers and the MUF factor M(3000)F2, depend in a systematic way on certain measurable quantities concerned with solar radiation. It should however be noted that the correlation between these indices and the actual ionospheric characteristics does not necessarily imply a causal relationship, but rather an indication of associated phenomena. Changes of solar activity in general contain three components:

- a fairly regular component with a period of about 11 years, which represents the well known cycle of solar activity;
- a component that has a quasi-period of about a year or a little less; and
- erratic fluctuations with periods of less than a month.

2. Sunspot numbers

For studies of the main component of the solar cycle the 12-month running mean sunspot number R_{12} is used because the resultant smoothing considerably reduces complicated rapidly-varying components but does not obscure the slowly varying component.

The definition of R_{12} is:

$$R_{12} = \frac{1}{12}\left[\sum_{n-5}^{n+5} R_k + \frac{1}{2}\left(R_{n+6} + R_{n-6}\right)\right] \tag{1}$$

in which R_k is the mean of the daily sunspot numbers for a single month *k*, and R_{12} is the smoothed index for the month represented by $k = n$.

The two main disadvantages in the use of R_{12} are:

- the most recent available value is necessarily centred on a month at least 6 months earlier than the present time;
- it cannot be used to predict the shorter-term variation in solar activity.

Nonetheless, R_{12} appears to be the most useful parameter for long-term studies and predictions concerning the F2 layer.

3. Index Φ

Consistent and reasonably long series of observations of the solar radio noise flux at about 10 cm wavelength have been made by Canadian, Japanese and other laboratories. The monthly mean, Φ, of the daily values at Ottawa, expressed in units of 10^{-22} Wm^{-2} Hz^{-1}, should be regarded as the reference data for this index. Φ is more closely correlated with E-layer critical frequency than are noise flux values at other wavelengths [Kundu, 1960]. As the solar flux observations are only available from 1947, the sunspot numbers remain one of the longest series of observations of a natural phenomenon. Therefore, the continued collection and recording of sunspot observations is encouraged.

4. Ionospherically derived solar activity index, IG

An index IG, an ionospherically derived solar activity index for prediction of foF2 has been developed [Liu *et al.*, 1983] especially for use with the Oslo version of the CCIR maps (see also Opinion 82).

5. Other indices

An index I_{F2} has been developed, based on measurement of foF2 at noon at long-established ionospheric observatories. Minnis [1964] showed that I_{F2} was more closely correlated with foF2 than any other index available at that time. A further index, *T*, developed in Australia [IPSD, 1968] uses measured data from 30 stations and is based on the mean of the monthly median values of foF2 at each hour. Apart from the use of data from all hours, the derivation of the index is similar to that for I_{F2}.

6. Correlation between various indices

The following figures and equations show relationships between observed values of R_{12}, Φ, IG_{12} and I_{F2}.

Figure 1 shows the mean relationship between R_{12} and Φ as determined from data for the years 1947-1966 [Joachim, 1966a, 1966b]. This corresponds to the expression:

$$\Phi = R_{12} + 46 + 23e^{-0.05\,R_{12}} \tag{2}$$

Stewart and Leftin [1972] have examined the relationship between R_{12} and Φ_{12}. They propose the equation, also evaluated in Fig. 1, of:

$$\Phi_{12} = 63.7 + 0.728\,R_{12} + 8.9 \times 10^{-4}\,R_{12}^2 \tag{3}$$

On the basis of data for the years 1943-1981 [Liu *et al.*, 1983], the relationship between R_{12} and IG_{12} is given by:

$$IG_{12} = -\,8.2 + 1.426\,R_{12} - 0.00257\,R_{12}^2 \tag{4}$$

Several workers have considered the relationship between R_{12} and I_{F2}. Using data for the years 1938-1960, Barclay [1962] concluded that values are consistent with:

$$R_{12} = 11.44 + 0.478\,I_{F2} + 0.00278\,I_{F2}^2 \tag{5}$$

This expression is shown evaluated in Fig. 2.

Joachim [1966a] has examined the relationship between R_{12} and I_{F2} separately for increasing and for decreasing solar activity. His overall mean relationship (see Fig. 2) is given by:

$$I_{F2} = (2.05 + 0.001\,R_{12})\,R_{12}^{(0.946\,-\,0.00047\,R_{12})} - 20 \tag{6}$$

Muggleton and Kouris, [1968] have produced separate expressions for the relationship between R_{12} and I_{F2} for each half solar cycles between 1938 and 1958.

Table I gives relationships for different months between the index *T* and R_{12} [IPSD, 1968].

It should be noted that slightly different forms of the above relationships will apply to different sunspot cycles.

TABLE I – *Relationship between T, Ionospheric index used by Australian Administration and* R_{12}

$$T = c + d \cdot R_{12}$$

Month	Ordinates at origin *(c)*	Slope *(d)*
January	−1.58	0.96
February	0.81	0.94
March	−0.65	0.97
April	−0.54	0.99
May	−0.06	1.00
June	0.34	1.01
July	−0.18	1.00
August	1.19	0.97
September	2.70	0.93
October	1.87	0.93
November	2.45	0.92
December	−0.04	0.96

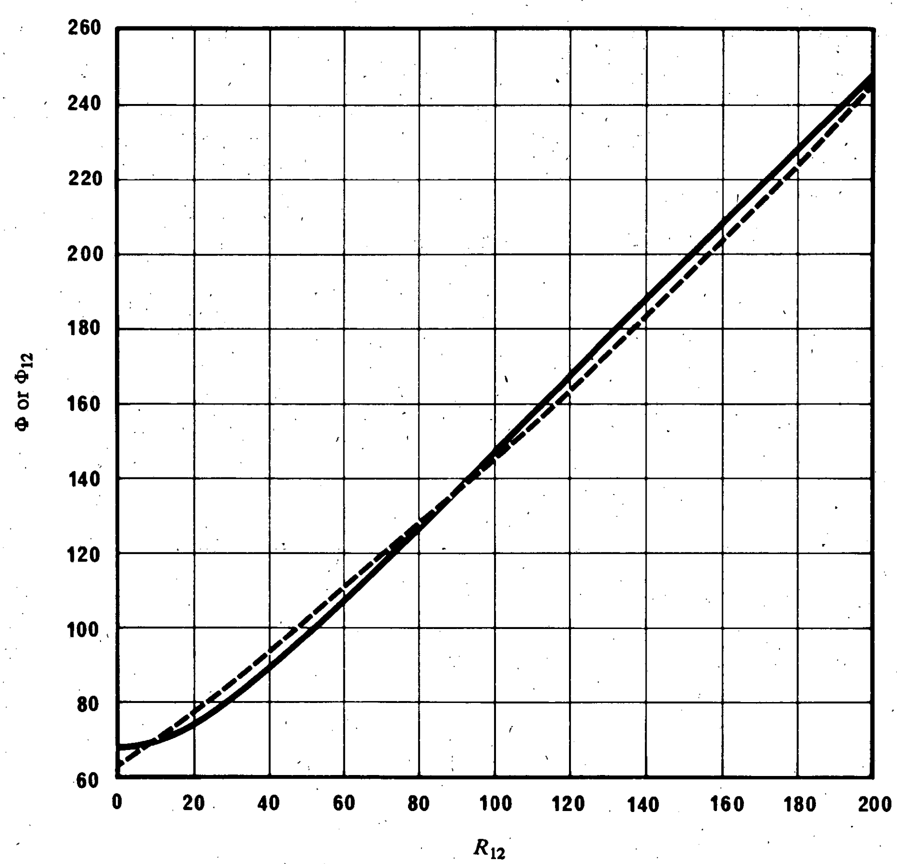


FIGURE 1 – *Relationship between* R_{12} *and* Φ *or* Φ_{12}

——— relationship with Φ (from equation (2))

– – – – relationship with Φ_{12} (from equation (3))

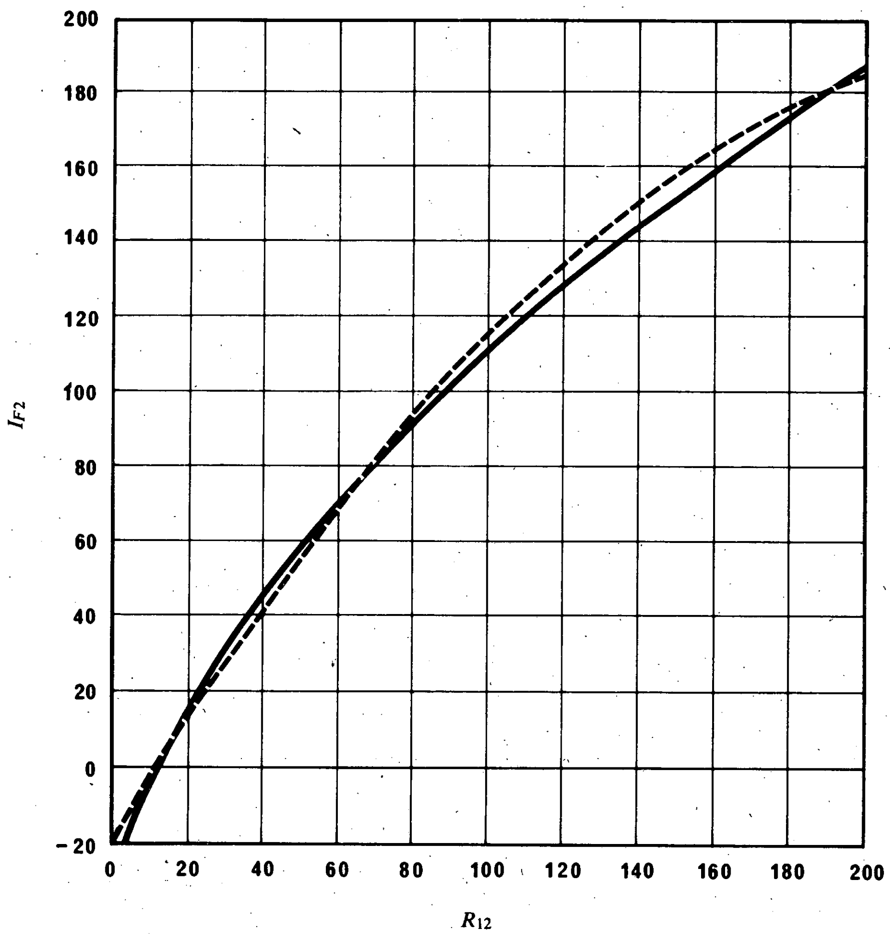


FIGURE 2 – *Relationship between R_{12} and I_{F2}*

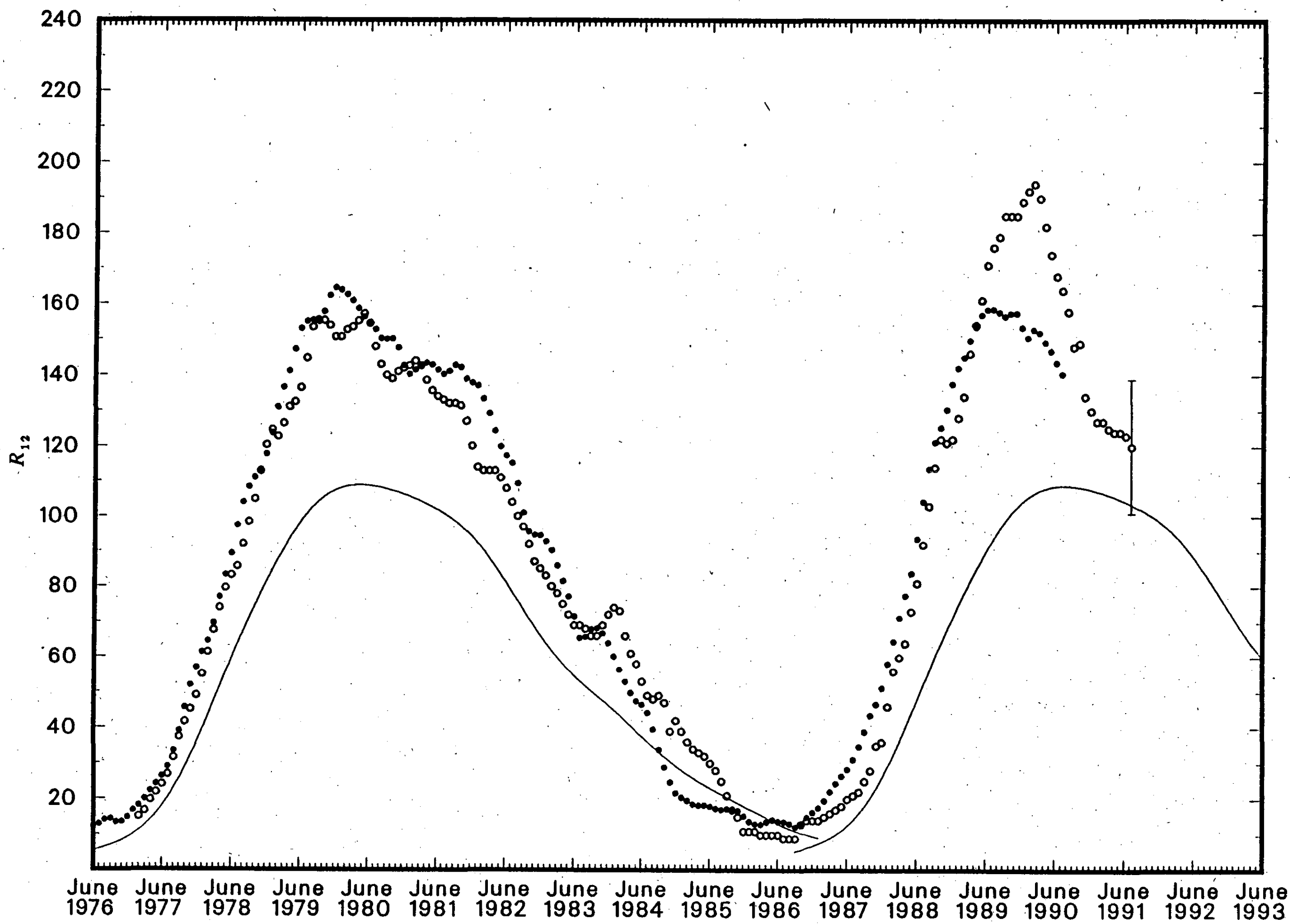
——— from equation (5)
– – – – from equation (6)

7. The prediction of indices

There is as yet no method whereby it is possible to predict accurately indices for the next sunspot cycle, or, more generally, for a cycle which has not yet begun. Indices that have been calculated by using harmonic analysis or by using empirical and statistical laws applied to observations over some earlier and even recent cycles, have not proved useful in predicting those for a new cycle. After a sunspot minimum has been observed, future development of the cycle can be extrapolated to a certain extent, although the deviations have been observed to be rather extreme.

A study undertaken by the Secretariat of the CCIR in 1956 of several different kinds of prediction methods concluded that it was not possible to improve on an error of approximately 10 in the prediction of the solar index, R_{12}. Only the statistical methods (comparison of cycles or autocorrelation) are considered useful, the methods based on harmonic analysis having never produced satisfactory results.

In the United States of America R_{12} is predicted using an improvement of the McNish-Lincoln objective method by Stewart and Ostrow [1970]. First a mean cycle is computed from all past values of R_{12} starting from the sunspot minimum of each cycle through eleven years thereafter. For prediction of a value in the current cycle the first approximation is the value of the mean cycle at the stated time after minimum (Fig. 3). This estimate is improved by adding a correction proportional to the departure of the last observed value for the current cycle from the mean cycle. With the current computer programmes a new prediction for each month of the remainder of the cycle can be made as soon as a new observed value becomes available. The statistical uncertainty of the prediction is fairly small for the first few months after the last observed value but becomes large for predictions 12 months or more in advance. As soon as a minimum is identified, new correction factors can be computed by including the observed values for the preceding cycle, for application to the new cycle.



Solar cycle 21 beginning June 1976 and
solar cycle 22 beginning September 1986

FIGURE 3 – *Predicted and observed sunspot numbers, R_{12}*

mean of cycles 8-21
observed smoothed
predicted smoothed one year ahead

In the USSR the prediction of relative sunspot numbers is based upon one of the different prediction methods given by Vitinski [1973].

Predictions of IG_{12} are also prepared regularly in the United Kingdom, using a modified version of the McNish-Lincoln method. Details are given by Smith [1986], who has shown that the resulting predictions of IG_{12} are more accurate than those of R_{12}, especially for prediction periods more than one year ahead.

Predictions of the index I_{F2}, six months into the future, are prepared regularly in the United Kingdom by extrapolating the 12-monthly running mean value. The procedure used to determine the future trend is to match values for the current solar cycle of activity with those for earlier cycles; extension is by reference to the magnitude and rate of change at the same phase in the former cycles [Smith, 1968]. Assessments made subjectively by this method are normalized to be consistent with values indicated by alternative means at times near solar maximum and minimum, where the cycle has turning points. Suitable statistical relationships, such as the variation of R_{12} for different times after sunspot maximum and minimum in terms of its maximum value for the cycle, serve to provide the required information on cycle behaviour, with sunspot numbers so derived being converted to values of I_{F2} using the formulae given in § 6 above.

Predictions of Φ_{12}, based on the McNish-Lincoln method, are carried out by the CCIR Secretariat.

Measured and predicted values of R, Φ, IG, I_{F2} and their 12-month running means are published in the monthly circulars of the CCIR as well as in the ITU Telecommunication Journal.

8. Comparison of indices

Studies of the prediction errors in foF2 resulting from the use of IG_{12} and R_{12} have been reported in [CCIR, 1982-1986a, b, c and d]. These comparisons were made using data obtained at many stations, covering a range of latitudes, longitudes and periods of comparison. Similar studies have been reported [Wilkinson, 1982; CCIR, 1985]. These studies were undertaken using at least ten years of observations at 13 vertical incidence stations. Comparisons were made using IG, R_{12}, I_{F2} and T indices as well as others.

It is clear from these studies that there is little advantage to be gained in using one index over another. However, on balance there is a slight degree of favourability for ionospherically derived indices, for example IG_{12}. While the difference in accuracy shown by the use of this index is small, it is in the direction that would be expected from the use of a purely ionospheric index.

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[1982-86]: **a.** 6/181 (France); **b.** 6/188 (German Democratic Republic); **c.** 6/204 (Japan); **d.** 6/207 (People's Republic of China).

[1985]: IWP 6/1 Doc. 256 (USA).

RECOMMENDATION 434-4

CCIR ATLAS OF IONOSPHERIC CHARACTERISTICS

(Question 25/6)

(1966–1970–1974–1978–1982)

The CCIR,

CONSIDERING

(a) that the current edition of the Atlas consists of Report 340-5, published separately, together with associated data tapes and computer programs;

(b) that the Atlas contains reference data and formulations of value in assessing characteristics of radio-wave propagation and of the state of the ionosphere;

(c) that requirements for these data vary in different applications;

UNANIMOUSLY RECOMMENDS:

1. that for the estimation of the basic MUF by means of a sufficiently powerful computer, use should be made of the data contained in Part 12 of Report 340-6.

2. that for the estimation of the basic MUF by manual means, use should be made of the data contained in Part 10 of Report 340-6.

3. that for the estimation of foEs and fbEs use should be made of the data contained in Part 6 of Report 340-6.

4. that for the estimation of h'F and h'F,F2 use should be made of the data contained in Part 8 of Report 340-6.

5. that for the estimation of the percentage of occurrence of spread F use should be made of the data contained in Part 7 of Report 340-6.

6. that for the determination of a model of the vertical distribution of electron density in the E and F regions use should be made of the data contained in Part 9 of Report 340-6.

Note 1 – Administrations and organizations, as well as the IFRB, having access to a computer, should use the computer versions of the Atlas; in other cases, the manual methods in the Atlas should be used.

Note 2 – The Director, CCIR, is requested to keep computer programs and magnetic data tapes available for distribution, as listed in Resolution 63.

RECOMMENDATION 533-2

ESTIMATING SKY-WAVE FIELD STRENGTH AT FREQUENCIES BETWEEN 2 AND 30 MHz

(Study Programme 30A/6)

(1978-1982-1990)

The CCIR,

CONSIDERING

(a) that the CCIR developed three separate computer-based methods of field-strength estimation as presented in Report 252, Supplement to Report 252 and Report 894:

- the method of Report 252 was the first internationally agreed procedure produced in 1970;
- the Supplement to Report 252 method was formulated in 1978 as a totally new procedure. It attempts to model a wide range of physical effects considered to be important in HF propagation and as such is rather complex. The associated computer program was completed in 1987;
- the Report 894 method has evolved from a simplified method developed by the CCIR for the use of the WARC HFBC. Its frequency range of applicability has been extended to 2-30 MHz making it suitable for propagation assessments in connection with other radio systems as well as HF broadcasting. Computer-based implementations of the Report 894 method are available;

(b) that tests against CCIR Data Bank D1 (see Resolution 63, Report 571 and Report 1150) show that the method of Report 894 has comparable accuracy to the other more complex methods;

(c) that Report 252 and its supplement are retained for use where appropriate;

(d) that associated computer codes have been formulated and made available to the CCIR Secretariat (see Resolution 63),

UNANIMOUSLY RECOMMENDS

1. that the information contained in Report 894 should be used in computerized prediction of sky-wave field strength at frequencies between 2-30 MHz;

2. that the methods described in Report 252 and its Supplement are appropriate for use in specific cases, e.g. where additional information is required, and for assistance in the development of improved methods;

3. that administrations and the CCIR should endeavour to improve prediction methods to enhance operational facilities and to improve accuracy.

SECTION 6F: IONOSPHERIC PROPAGATION PREDICTION AND APPLICATIONS AT FREQUENCIES ABOVE ABOUT 30 MHz

RECOMMENDATION 531-1

IONOSPHERIC EFFECTS INFLUENCING RADIO SYSTEMS INVOLVING SPACECRAFT

(Questions 36/6, 37/6)

(1978–1990)

The CCIR,

CONSIDERING

that ionospheric effects may influence the design of ISDN (Integrated Services Digital Network) and other radio systems involving spacecraft,

UNANIMOUSLY RECOMMENDS

that the information contained in Reports 262 and 263 should be used as required in the planning and design of such systems.

RECOMMENDATION 534-3

METHOD FOR CALCULATING SPORADIC-E FIELD STRENGTH

(Question 41/6)

(1978-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that propagation by sporadic E is an important source of interference at low VHF;

(b) that the calculation method of sporadic-E field strength given in Annex I to this Recommendation has been proved to be practical and reliable;

(c) that there exists no other practical method,

UNANIMOUSLY RECOMMENDS

1. that the calculation method in Annex I be adopted as the method to be used for estimation of sporadic-E field strength for the low- and mid-dip latitudes;

2. that more foEs and sporadic-E field strength data be collected, particularly in the high latitude regions. In the meantime, caution should be exercised if the method in Annex I is used in these regions.

ANNEX I

METHOD FOR CALCULATING SPORADIC-E FIELD STRENGTH

1. Introduction

The present text sets out a statistical method for calculating the field strength of signals propagated by means of ionospheric sporadic E (Es) at VHF and, possibly, at higher portions of the HF bands, for distances up to 4000 km. The calculation is based upon the fact that the field strength is very closely correlated with foEs, that is to say, the critical frequency of sporadic-E layer at vertical incidence at the path mid-point. It should be noted that the method is suitable for application to an ionospheric radio circuit in the case where the regular propagation mode via the E or F2 layer does not exist. When using the method at HF therefore, caution should be exercised if the possibility of regular layer propagation exists. (See Recommendation 533 for regular-layer propagation.) The method, which is essentially the same as the method described by Miya and Sasaki [1966], Miya *et al.*, [1978], has been refined taking particular account of data obtained from the EBU ten year measurement campaign [EBU, 1976] for the modification of the original ionospheric attenuation chart and also with the provision of some charts of foEs submitted by members of Interim Working Party 6/8. Since the data provided by the Recommendation refer to geomagnetic latitudes between ± 60°, it is necessary to continue to examine the applicability of the method, especially in the high latitude regions.

Experimental results which show good agreement with this prediction method have been provided by a USSR experiment on 9, 14, 24 and 44 MHz over a 1050 km path [CCIR, 1978-82] and also by the Argentine Republic on 47.620 MHz over a 1070 km path [Giraldez, 1984], both being in mid-magnetic latitude regions.

In the equatorial region some experimental results of medium distance propagation (500-2000 km), clearly indicate Es propagation, which must be distinguished from the much more important effects of trans-equatorial propagation (TEP) in the area (see Report 259). Low latitude Es propagation field strength is approximately the same as estimates for mid-latitudes in this Annex. However the parameter showing the greatest change is the percentage of time as a function of the vertical incidence critical frequency (foEs) (Figs. 2 to 6 for middle magnetic latitudes). Therefore, alternative Figs. 16 to 21 are provided for use in the low magnetic latitude region.

The method has the following features:

- Es field strength is predicted by means of the statistical correspondence of a value of ionospheric attenuation to that of foEs at a given rate of occurrence;
- the ionospheric attenuation of the Es signal is represented by a function of the ratio of the signal frequency f to foEs and the surface distance between the transmitting and receiving stations;
- some useful probability charts and world maps of foEs are provided for quick and easy evaluation of the Es field strength.

2. Formula for sporadic-E field strength

Es signal strength can be expressed as follows:

$$E = E_0 + P + G_t - L_t - \Gamma \quad \text{dB} \tag{1}$$

$$E_0 = 105 - 20 \log l \quad \text{dB} \tag{2}$$

where

E: predicted field strength (dB(μV/m));

E_0: theoretical inverse distance field strength (dB(μV/m)), for 1 kW radiated power and isotropic transmitting antenna;

P: transmitter power (dB(1 kW));

G_t: gain of the transmitting antenna relative to an isotropic antenna, (dB);

L_t: loss of the transmitting antenna, (dB);

Γ: ionospheric attenuation (dB) as shown by the solid line curves in Fig. 1;

l: transmission path length (km), (see equation (5)).

For the calculation by computer, Γ for single-hop propagation signal, $\Gamma_{(1-\text{hop})}(d)$, is given approximately by:

$$\Gamma_{(1-\text{hop})}(d) = \left\{ \frac{40}{1 + \left(\frac{d}{130}\right) + \left(\frac{d}{250}\right)^2} + 0.2\left(\frac{d}{2600}\right)^2 \right\} \left(\frac{f}{\text{foEs}}\right)^2 + \exp\left(\frac{d - 1660}{280}\right) \tag{3}$$

and Γ for double-hop propagation signal, $\Gamma_{(2-\text{hop})}(d)$ approximately by:

$$\Gamma_{(2-\text{hop})}(d) = 2.6\, \Gamma_{(1-\text{hop})}\left(\frac{d}{2}\right) \tag{4}$$

and

l: transmission path length (km) is given by:

$$l = (d^2 + 4h^2)^{1/2} \tag{5}$$

where

h: height of Es layer; (km);

d: surface distance between the transmitting and receiving stations (km);

f: signal frequency (MHz);

foEs: critical frequency of sporadic-E at vertical incidence at a given rate of occurrence (MHz);

The accuracy with which equations (3) and (4) reproduce the measured values of Γ is indicated in Fig. 1 where they are plotted as the broken line curves. The use of equation (3) should be restricted to distances less than 2600 km with the values of f/foEs between 1 and 8, where the error is less than 5 dB. The use of equation (4) should be restricted to distances between 2600 and 4000 km, and to values of f/foEs between 2 and 5.5; the error will then be less than 10 dB.

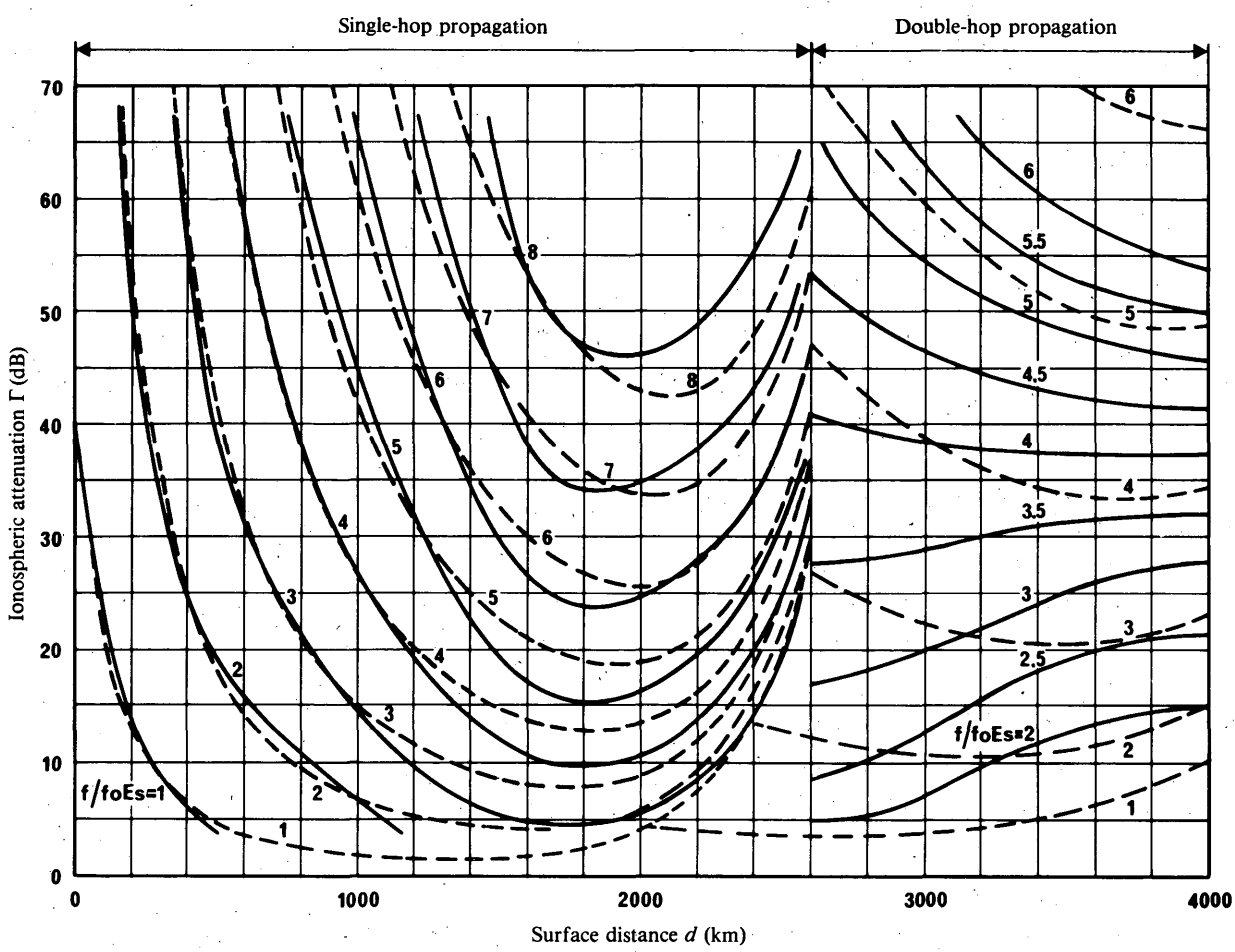

FIGURE 1 – *Chart of ionospheric attenuation* Γ *for Es propagation*

——— from observed values

– – – – from empirical formulae (3) and (4)

3. A procedure for calculating sporadic-E field strength

A procedure for calculating Es field strength is as follows:

- first step: calculate a value of E_0 corresponding to given value of l using equation (2);
- second step (path mid-point dip latitude outside ± 20°): read off a value of foEs at a given time percentage of occurrence in the desired region and season using one of Figs. 2 to 6. If a more accurate prediction is required, read off a value of the percentage of time that foEs exceeds 7 MHz at the path mid-point using a pertinent map of Figs. 12 to 15 and determine a value of foEs by drawing a new line on the relevant one of Figs. 2 to 6 as described in § 4.1. If a prediction of diurnal variation is required, read off a value of foEs on a pertinent figure of Figs. 7 to 11;
- second step (path mid-point dip latitude within ± 20°): determine the dip angle for the ionospheric reflection point and read off a value of foEs at a given percentage of time of occurrence under the desired region and season using Figs. 16 to 21;
- third step: calculate f/foEs;
- fourth step: using the solid line curves in Fig. 1, read off a value of Γ corresponding to the given value of d and the calculated f/foEs, or, for an approximate value, calculate Γ using equations (3) and (4);
- fifth step: calculate the predicted value of E by equation (1), using given values of P, G_t, L_t and the value obtained for Γ.

4. Probability of occurrence of foEs

It is necessary to clarify the statistical characteristics of foEs since it undergoes sporadic behaviour changes with location and time. The world map of foEs, such as that of Part 6 of Report 340, can be used for high accuracy of prediction. On the other hand, simplified statistical data of foEs are also very useful in cases where the general tendency of temporal variation is to be obtained.

For the purpose of predicting the average Es field strength, probability curves of foEs have been prepared for the five mid-latitude regions of Europe and North Africa, North America, Asia (Far East), South America and a buffer region between these regions as shown in Figs. 2 to 11. For low latitudes, probability curves of foEs have been prepared for America, Asia and Africa as shown in Figs. 16 to 21. The high latitude region characteristics need to be further clarified in the future.

4.1 *Mid-latitudes*

To provide detailed geographic characeristics of foEs, the world maps of the percentage of time for which foEs is equal to or greater than 7 MHz during the months of May-August (northern summer), November-February (southern summer), the months of March, April, September and October (equinoctial months, north and south) and for twelve months, are specifically included as Figs. 12-15 [Smith, 1976, 1978]. As may be seen in these world maps, contours of time percentage are shown between 60° geomagnetic (or dipole) north and south latitudes. A low latitude region around the dip equator is excluded.

Figures 2 to 6 show the relation between the value of foEs and the time percentage of its occurrence. In these figures, curves for the summer months, winter months and equinoctial months are all represented by straight lines connecting two points corresponding to values of time percentage exceeding 7 MHz and 10 MHz, respectively, of foEs. These are subject to the so-called Phillips' frequency-dependence rule. This rule is a strictly empirical one which works quite well at mid-latitudes for percentages of time less than about 30% and for frequencies above foE, the critical frequency of the normal E layer. Caution should be exercised in the use of the Phillips rule for frequencies above about 100 MHz and for equatorial and high latitudes. The Phillips rule is:

$$\log p = a + bf \tag{6}$$

where

p: probability of occurrence of foEs $> f$,

f: frequency (MHz),

a and b: are adjustable constants, such that b is the slope in a plot of $\log p$ as a function of f.

A curve showing the annual average, has values of time percentage of about one third of the corresponding values for the summer months in the low percentage of time ranges. For reference, probability curves are added to the respective figures for the period of daytime (0800-2300 h) in the summer months, when the most intense sporadic E is observed.

When there exists a difference between a value of time percentage of foEs for 7 MHz, as obtained by the world maps in Figs. 12, 13, 14 or 15 and that obtained by the average probability curve for a Region, as seen in Figs. 2 to 6, a value of foEs may be determined for a given percentage of time, by using a new probability curve redrawn so as to be parallel to the original curve in the respective region and displaced by an amount equal to the difference of those values.

Figures 7 to 11 exhibit diurnal variations of occurrence of foEs in a time block of 4 hours in the above four regions for the summer and non-summer months, according to their distinctive characteristics. It is noticeable that a definite minimum of foEs is observed shortly after midday in regions B and C, particularly in summer. For the purpose of predicting the detailed behaviour of Es signal strength, it may be necessary to show the diurnal variations of foEs in terms of a time block smaller than 4 hours.

4.2 *Low latitudes*

Figures 16 to 21 show the relation between the value of foEs and the time percentage of its occurrence for low latitudes. In these figures, a clear difference is observed between a very narrow belt around the dip equator (± 6° dip angle) and the adjacent region up to ± 20° dip, which might be called equatorial and sub-equatorial regions respectively. As seen from comparison with Figs. 2 to 6, the sub-equatorial region, but not the equatorial one, is subject to the Phillips law.

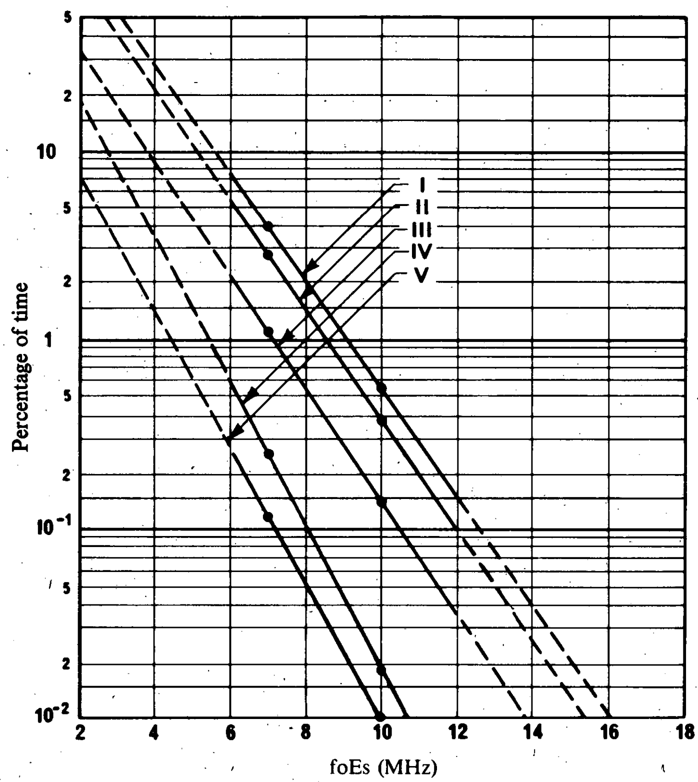

FIGURE 2 – *Values of foEs equalled or exceeded for indicated percentage of time for region A*

Region A: Europe and North Africa
I: May to August (0800-2300 h)
II: May to August
III: annual average
IV: March, April, September and October
V: November to February

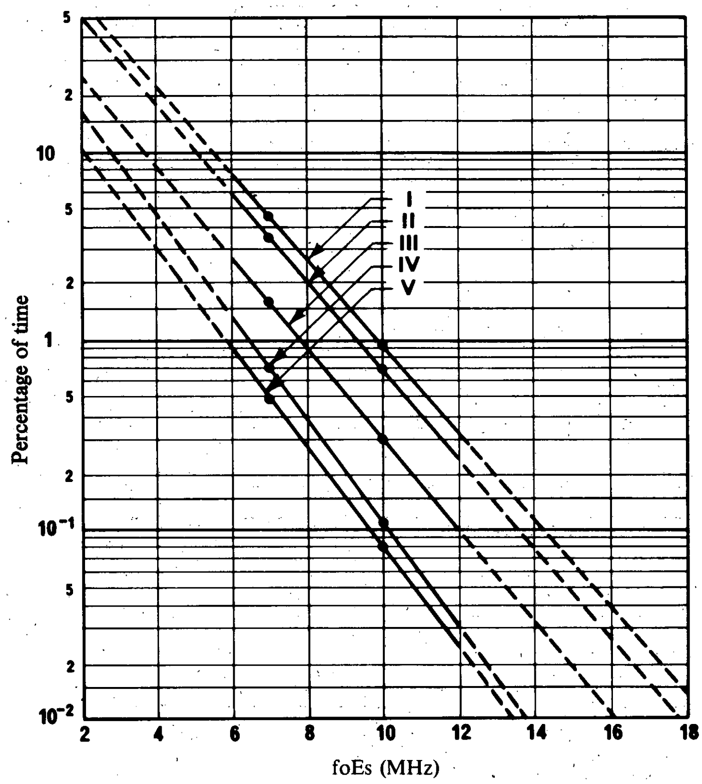

FIGURE 3 – *Values of foEs equalled or exceeded for indicated percentage of time for region B*

Region B: North America
I: May to August (0800-2300 h)
II: May to August
III: annual average
IV: March, April, September and October
V: November to February

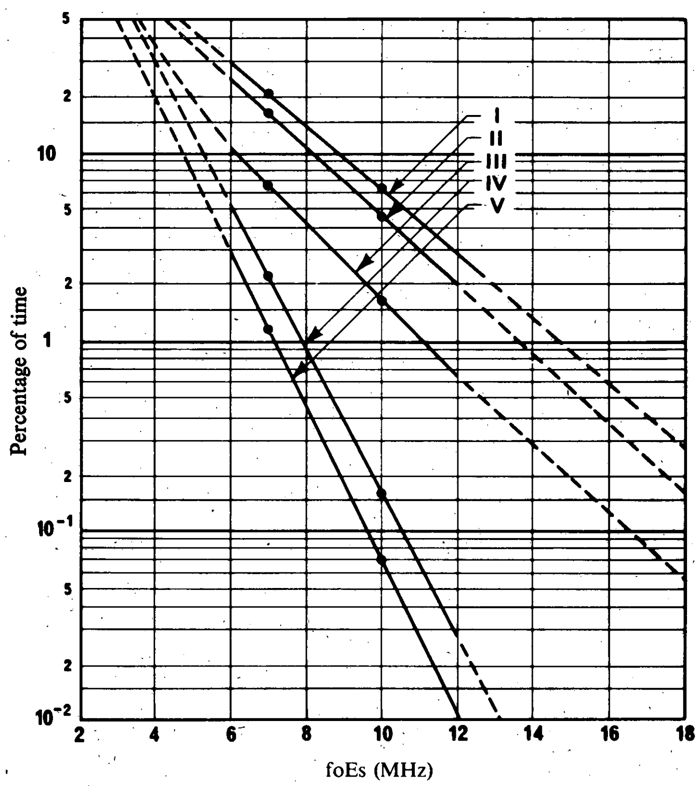

FIGURE 4 — *Values of foEs equalled or exceeded for indicated percentage of time for region C*

Region C: Asia (Far East)
I: May to August (0800-2300 h)
II: May to August
III: annual average
IV: March, April, September and October
V: November to February

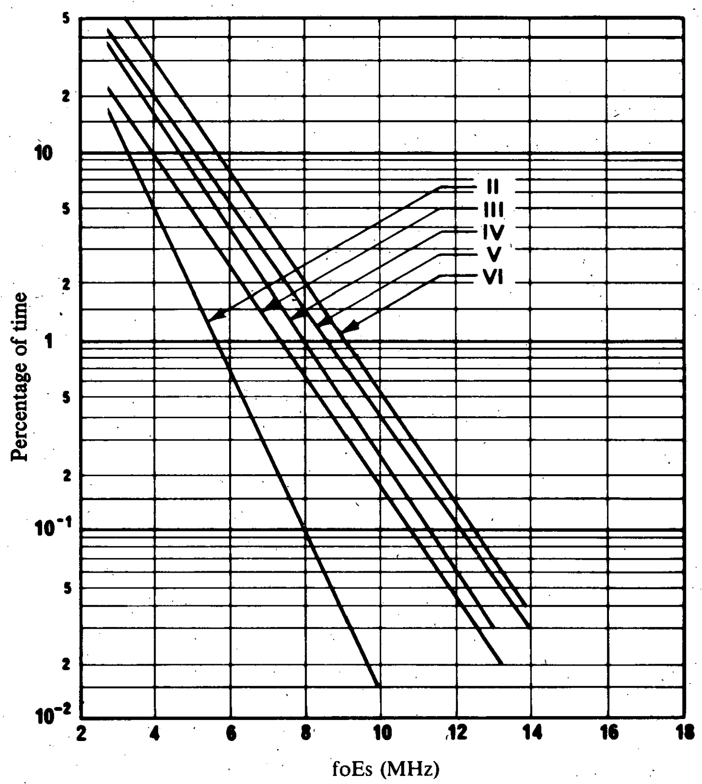

FIGURE 5 – *Values of foEs equalled or exceeded for indicated percentage of time for region D*

Region D: South America
II: May to August
III: annual average
IV: March, April, September and October
V: November to February
VI: November to February (0800-2300 h)

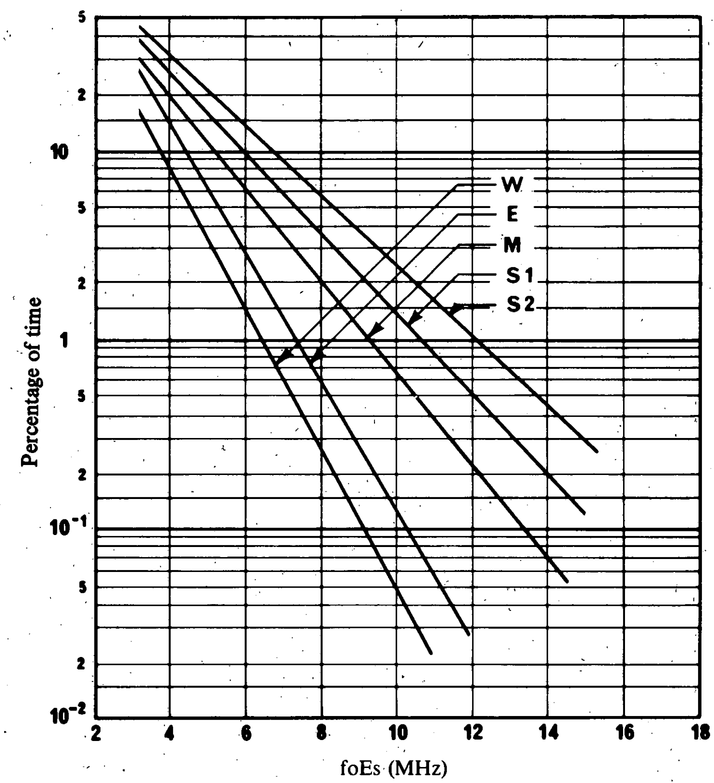

FIGURE 6 – *Values of foEs equalled or exceeded for indicated percentage of time*

Mean value: regions A, B, C and D
S1: summer
S2: summer (0800-2300 h)
M: annual average
E: equinox
W: winter

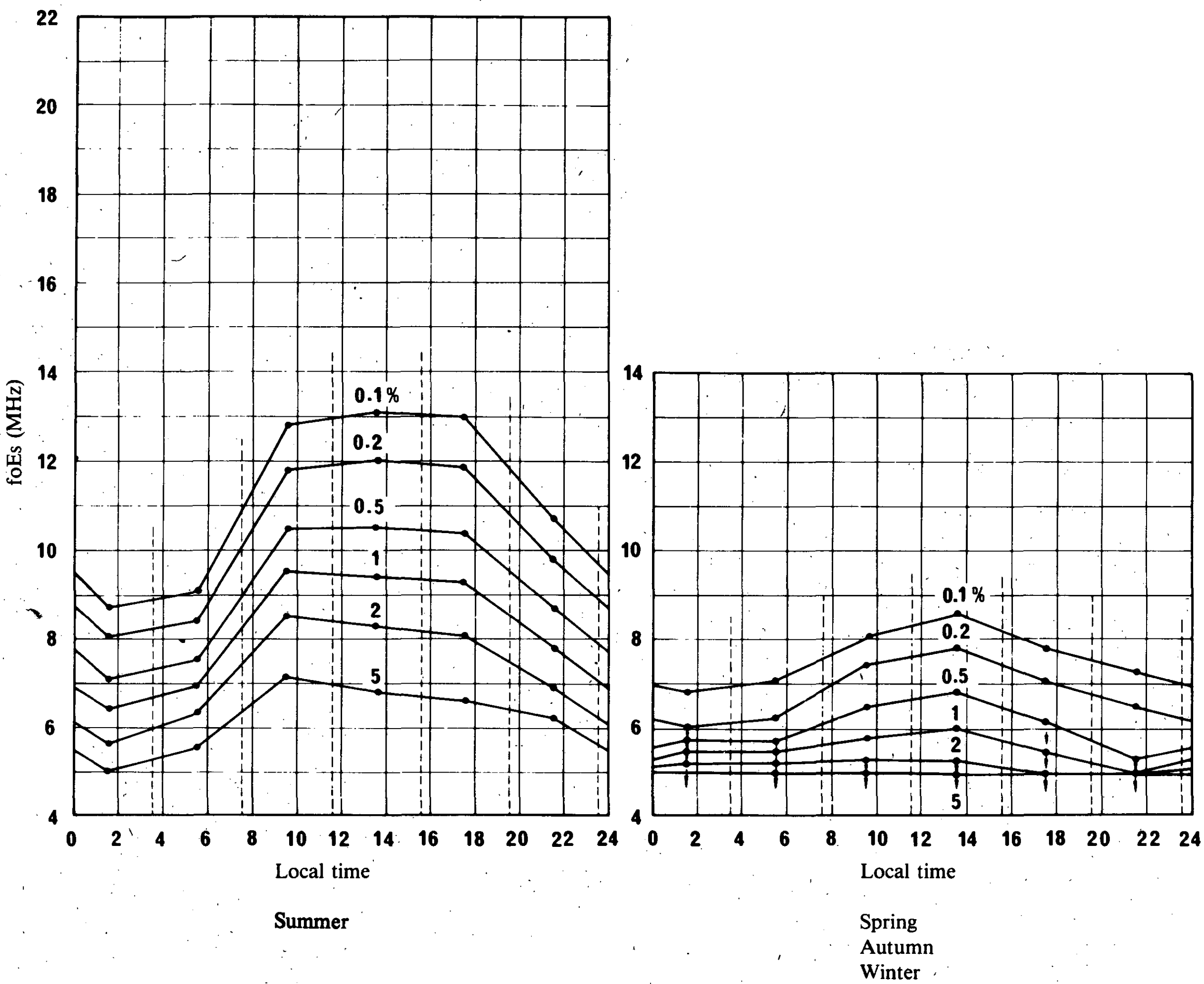

FIGURE 7 – *Values of foEs equalled or exceeded for the percentage of time indicated as the parameter on the curve during time blocks shown separated by the dotted vertical lines of 4 hours for region A (Europe and North Africa)*

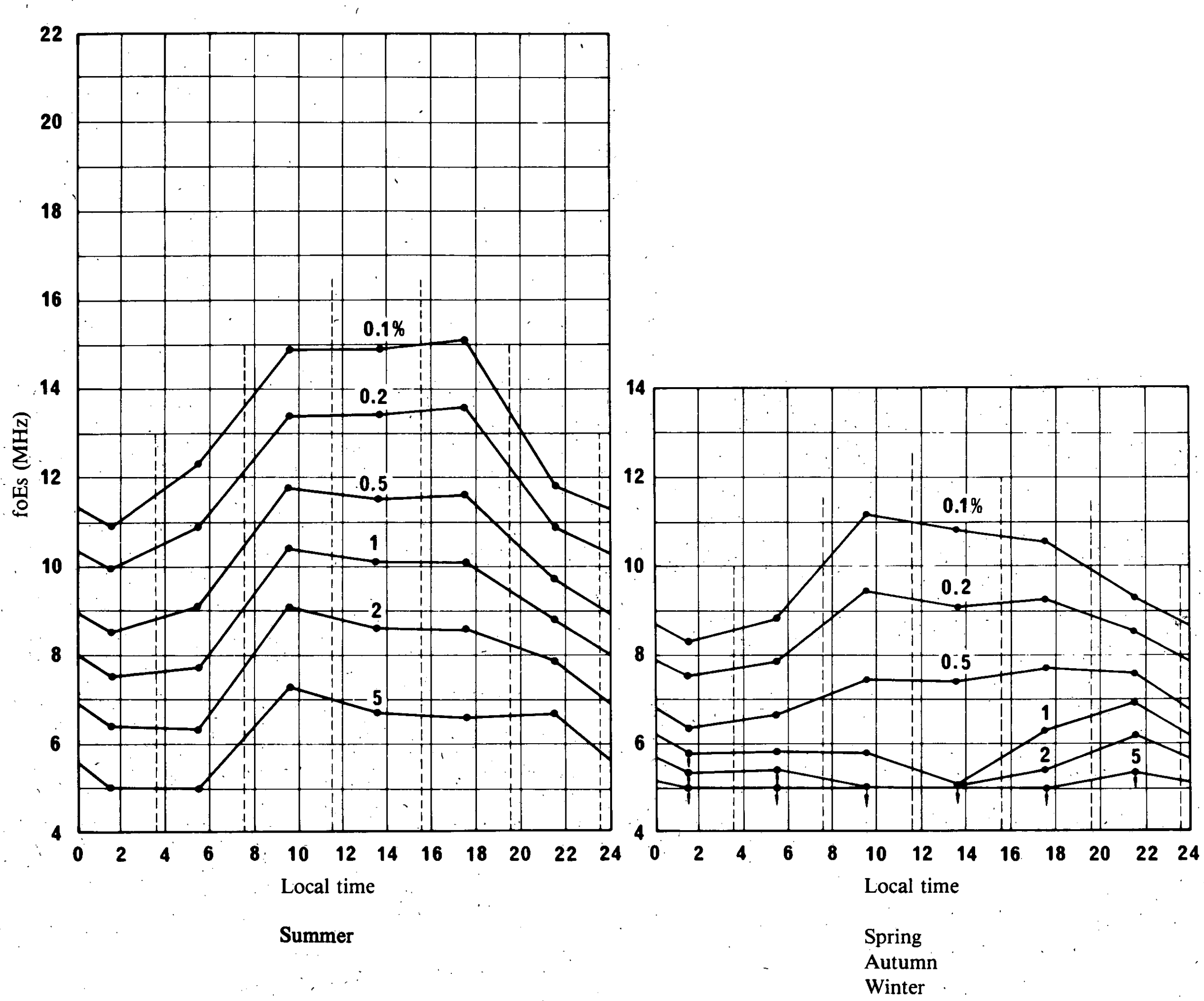

FIGURE 8 – *Values of foEs equalled or exceeded for the percentage of time indicated as the parameter on the curve during time blocks shown separated by the dotted vertical lines of 4 hours for region B (North America)*

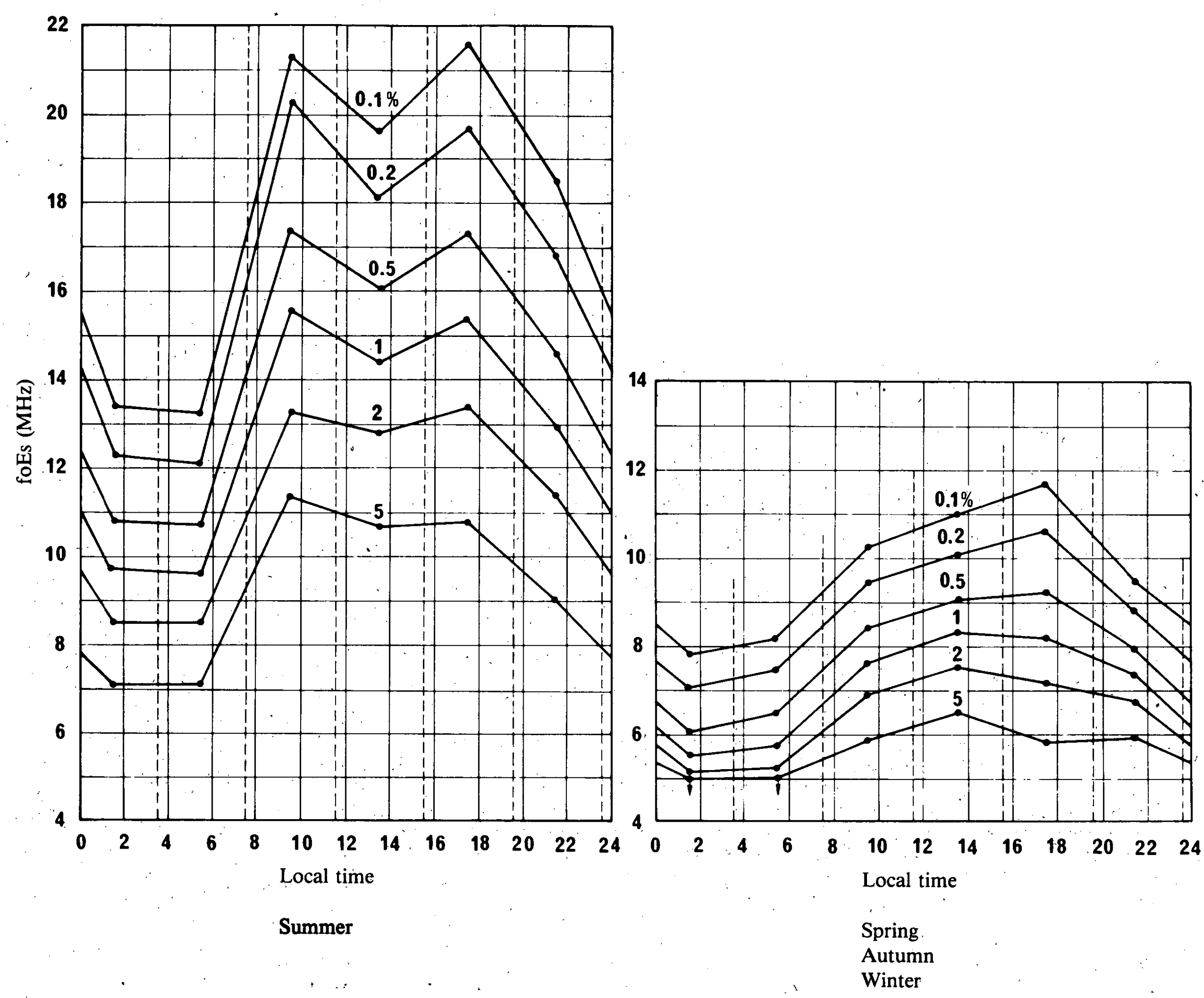

FIGURE 9 – *Values of foEs equalled or exceeded for the percentage of time indicated as the parameter on the curve during the time blocks shown separated by the dotted vertical lines of 4 hours for region C (Asia (Far East))*

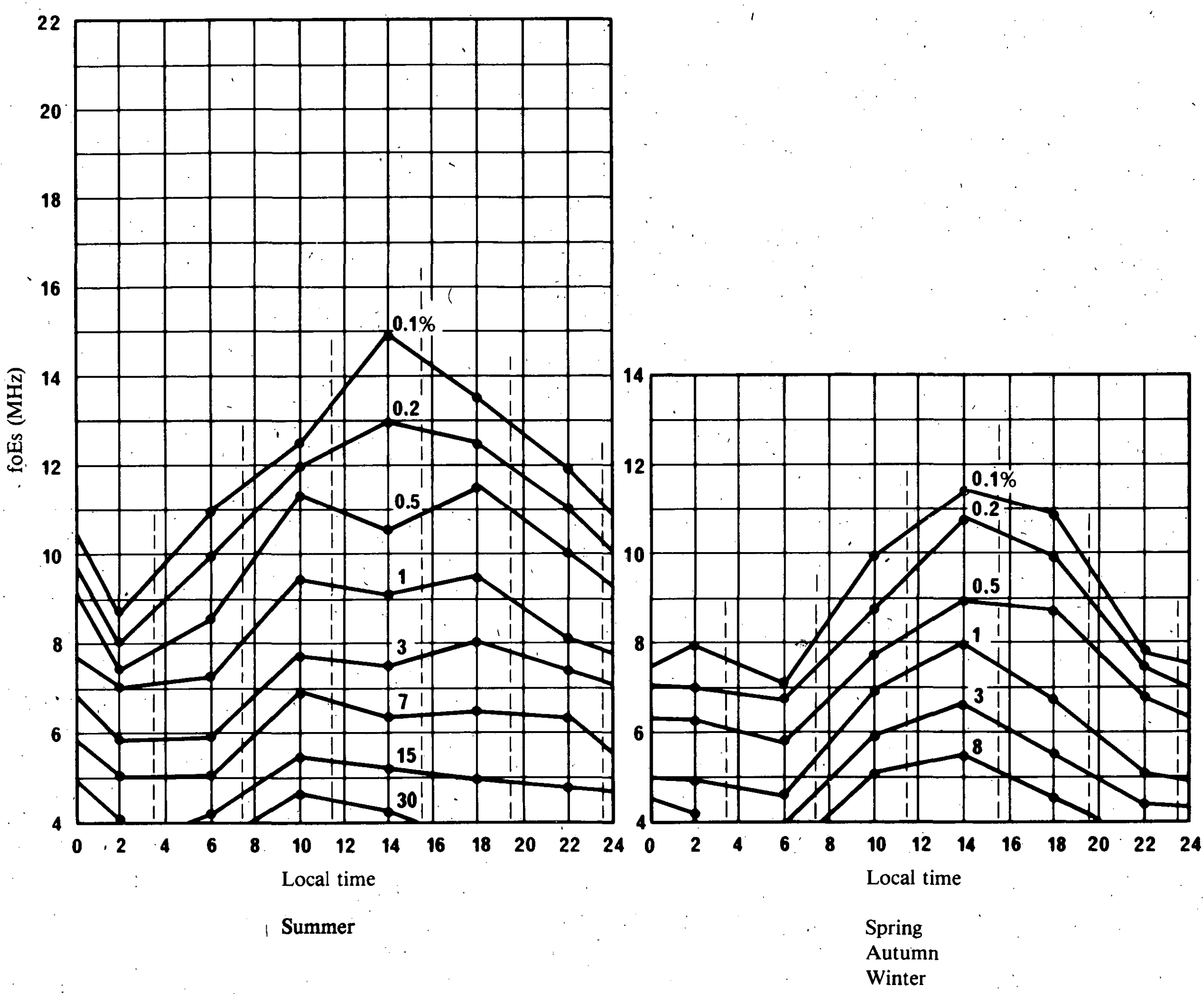

FIGURE 10 – *Values of foEs equalled or exceeded for the percentage of time indicated as the parameter on the curve during time blocks shown separated by the dotted vertical lines of 4 hours for region D (South America)*

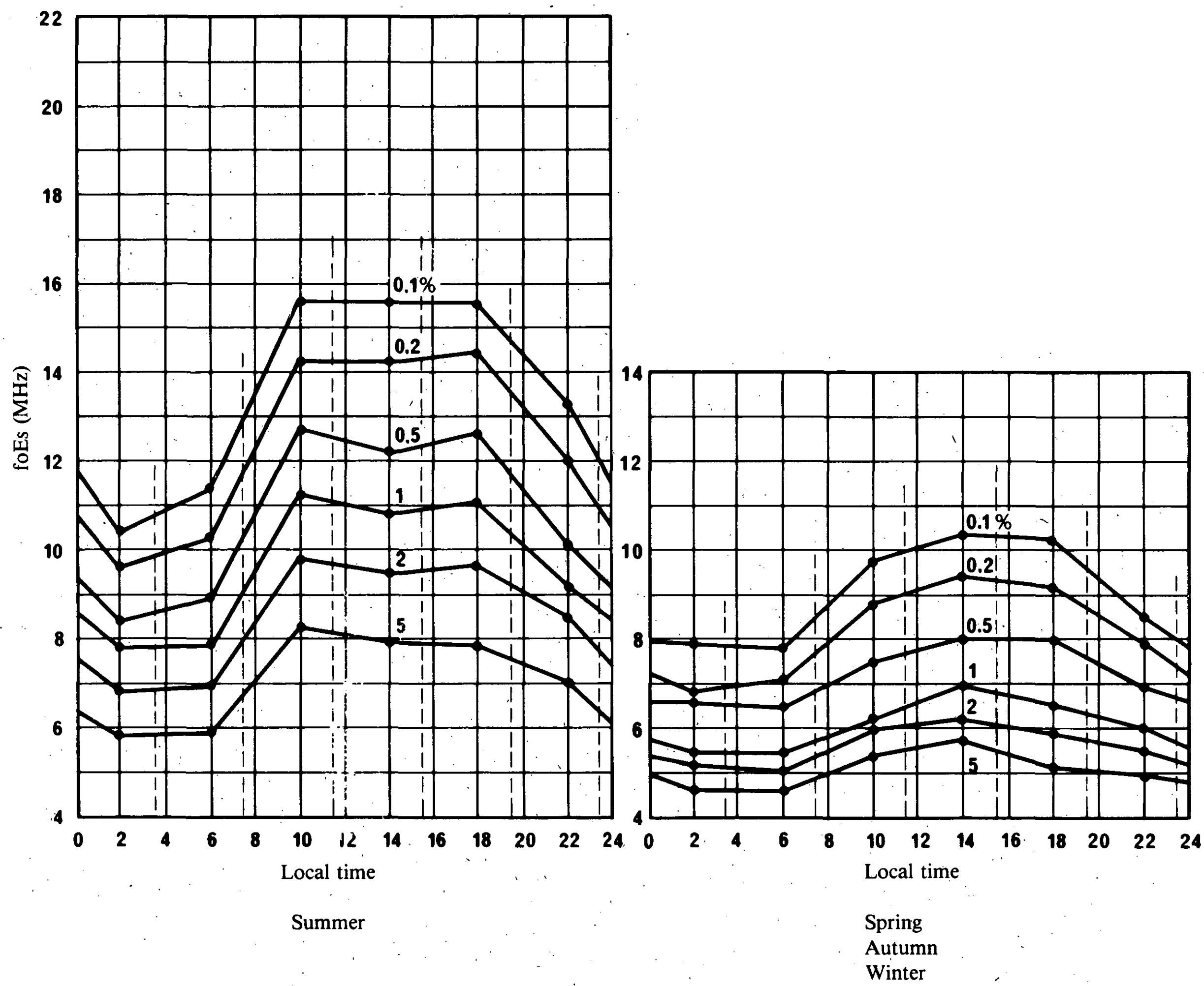

FIGURE 11 – *Mean values of foEs equalled or exceeded for the percentage of time indicated as the parameter on the curve during time blocks shown separated by the dotted vertical lines of 4 hours for regions A, B, C and D*

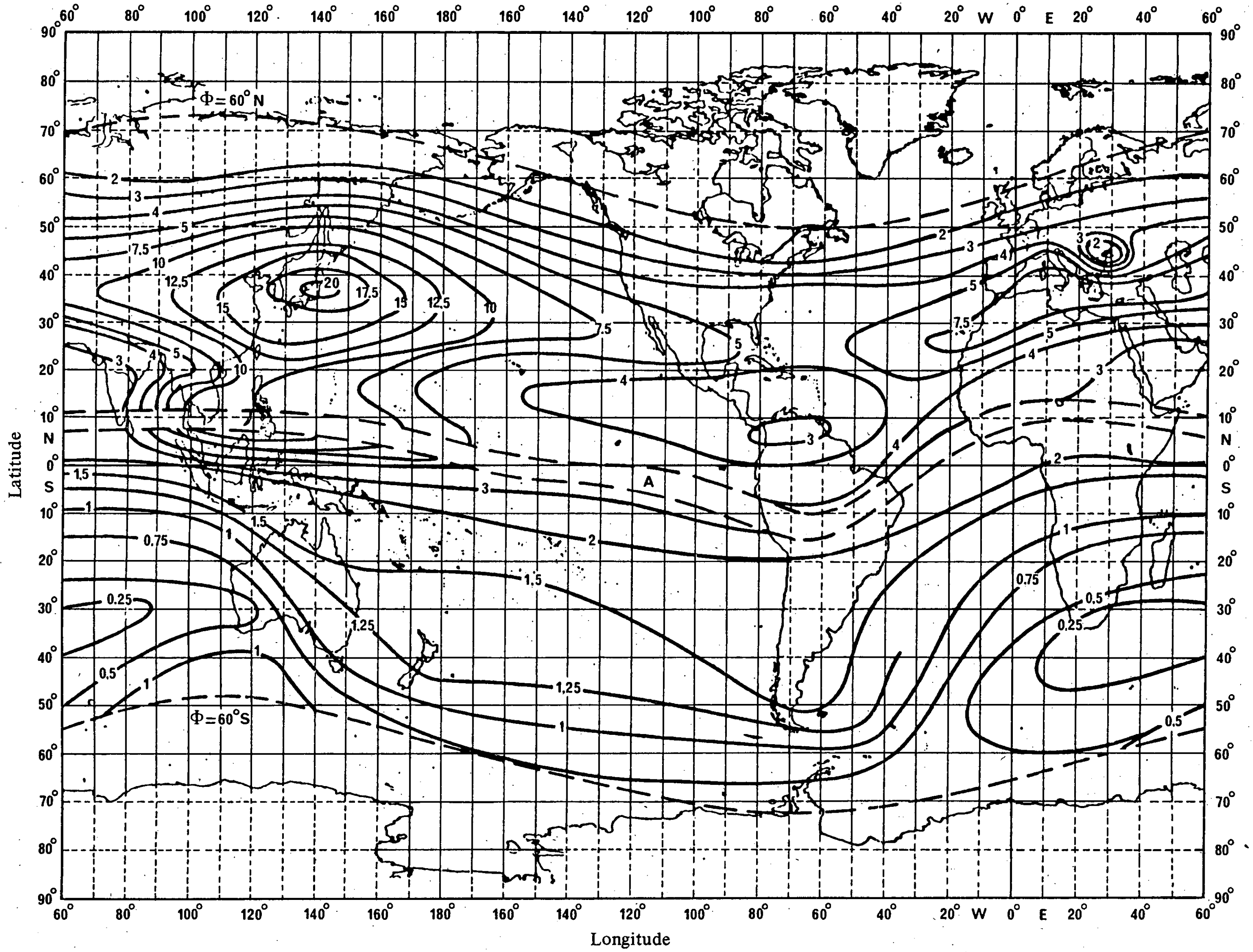

FIGURE 12 – *Percentage of time for which sporadic E (foEs) equals or exceeds 7 MHz at vertical incidence in the mid-latitude zones for the months May, June, July and August*

A: low latitude region (see § 4)

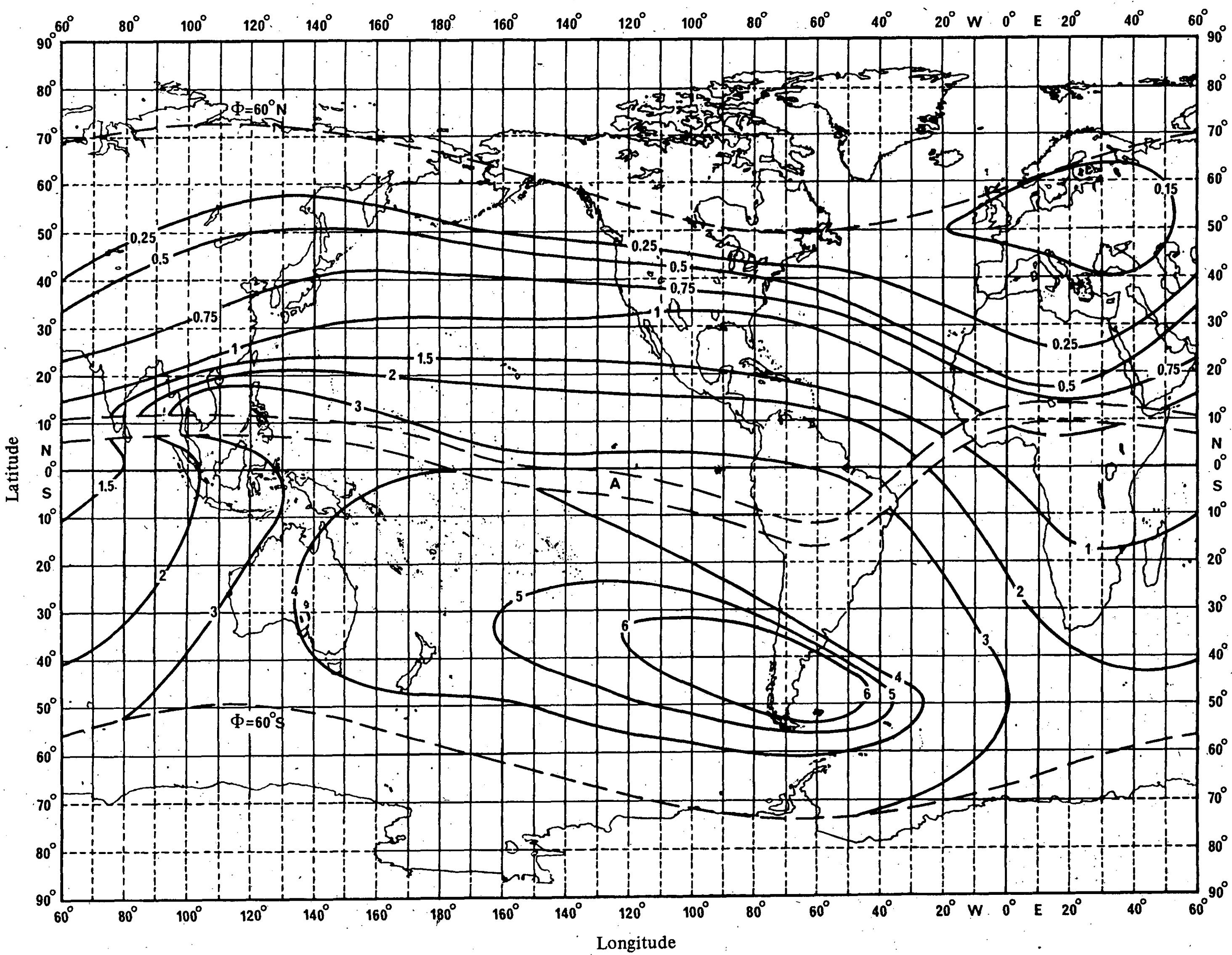

FIGURE 13 – *Percentage of time for which sporadic E (foEs) equals or exceeds 7 MHz at vertical incidence in the mid-latitude zones for the months November, December, January and February*

A: low latitude region (see § 4)

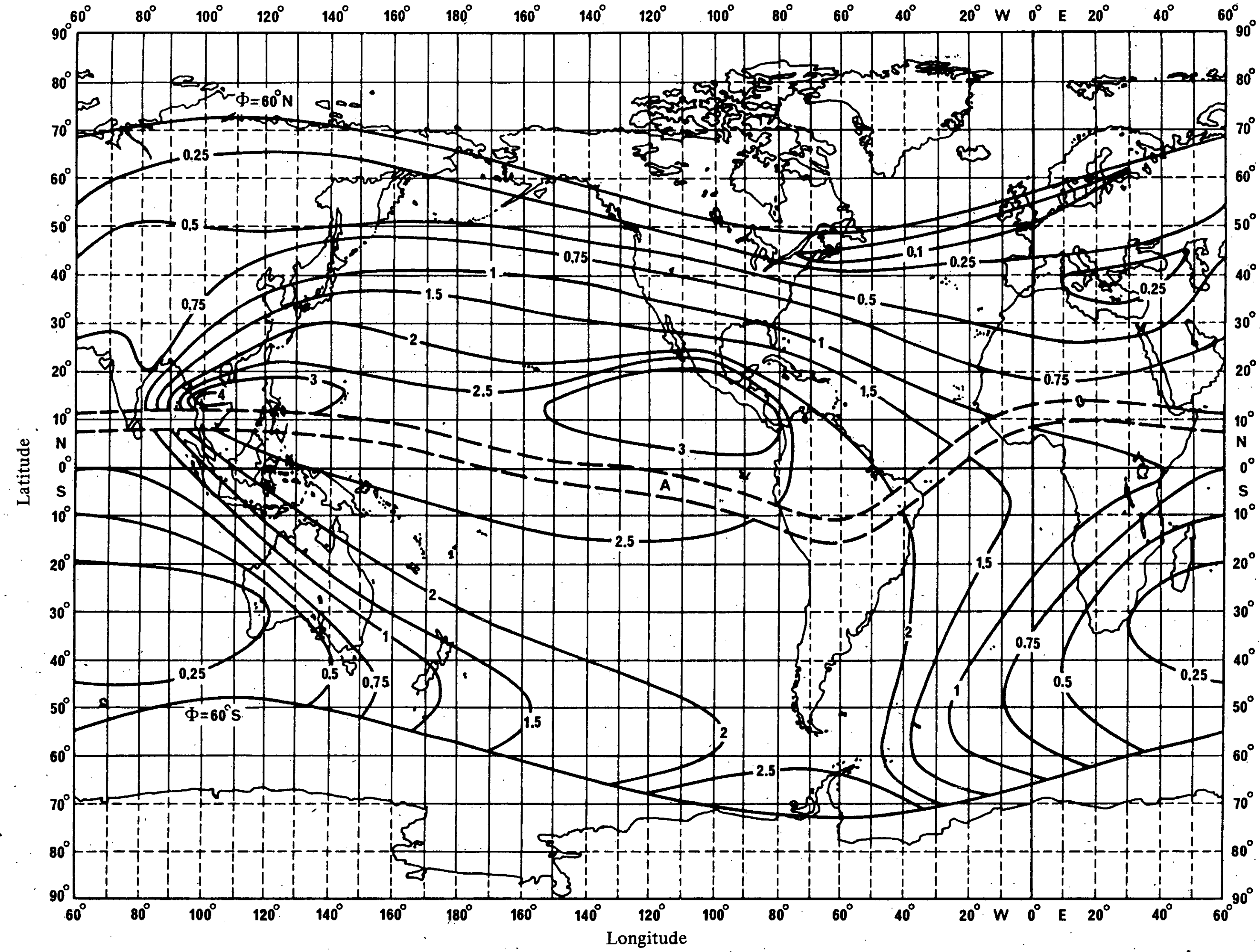

FIGURE 14 – *Percentage of time for which sporadic E (foEs) equals or exceeds 7 MHz at vertical incidence in the mid-latitude zones for the months March, April, September and October*

A: low latitude region (see § 4)

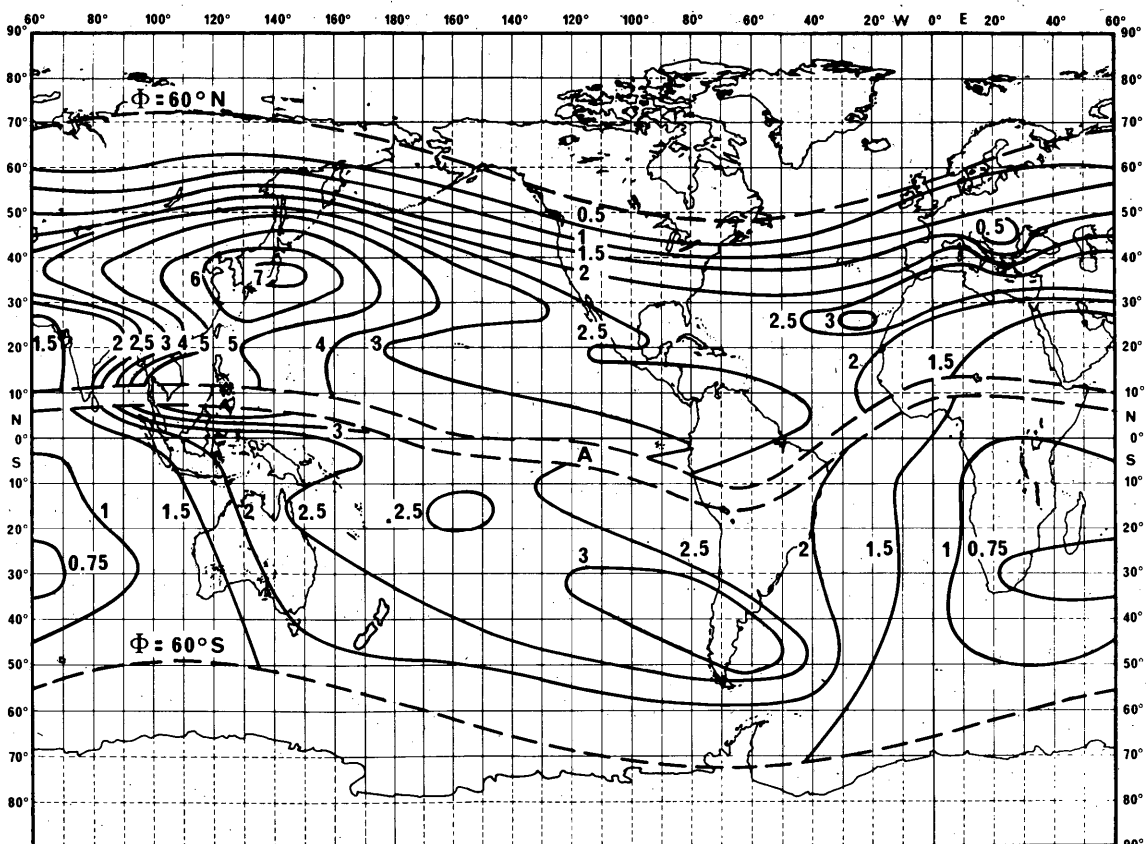

FIGURE 15 – *Percentage of time for which sporadic E (foEs) equals or exceeds 7 MHz at vertical incidence in the mid-latitude zones during the 12 months of the year*

A: low latitude region (see § 4)

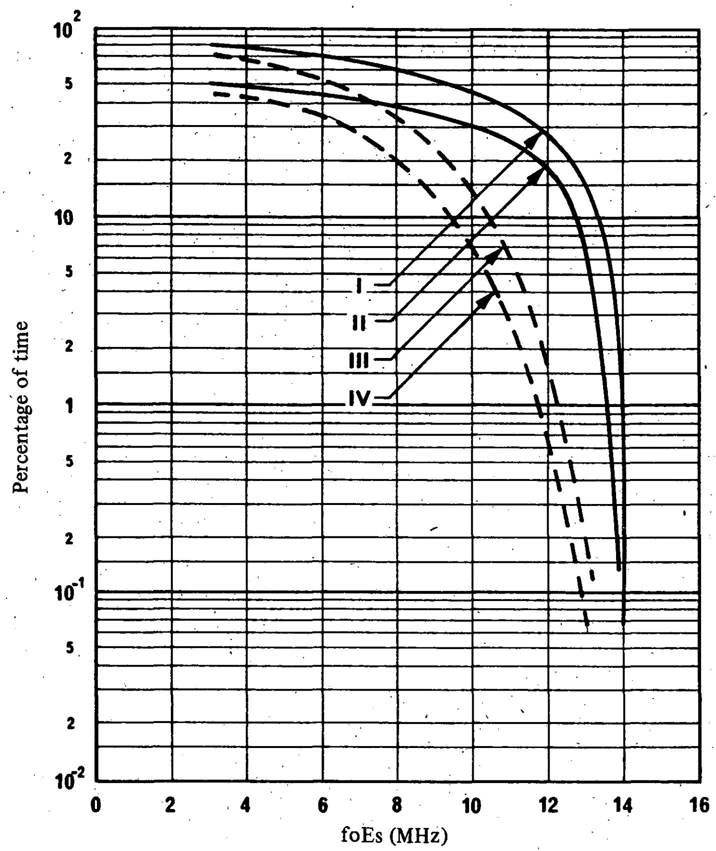

FIGURE 16 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region E: Equatorial Asia (±6° dip latitude)

I: maximum solar activity years (0600-1800 h). Annual average

II: maximum solar activity years. Annual average

III: median and low solar activity years (0600-1800 h). Annual average

IV: median and low solar activity years. Annual average

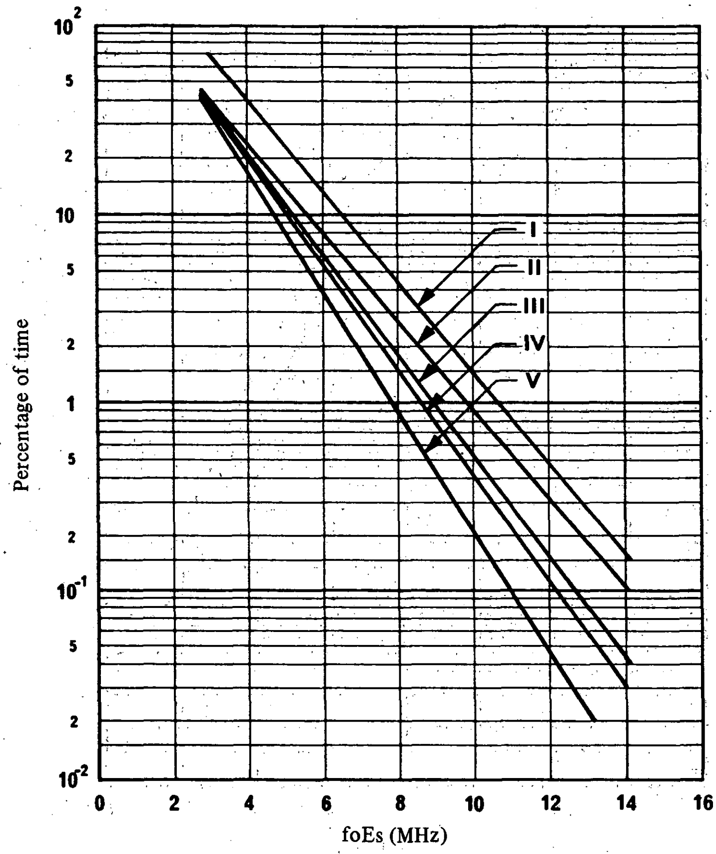

FIGURE 17 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region E: Sub-equatorial Asia (between ±6° and ±20° dip latitude)

I: summer (0600-1800 h)

II: summer

III: annual average

IV: equinox

V: winter

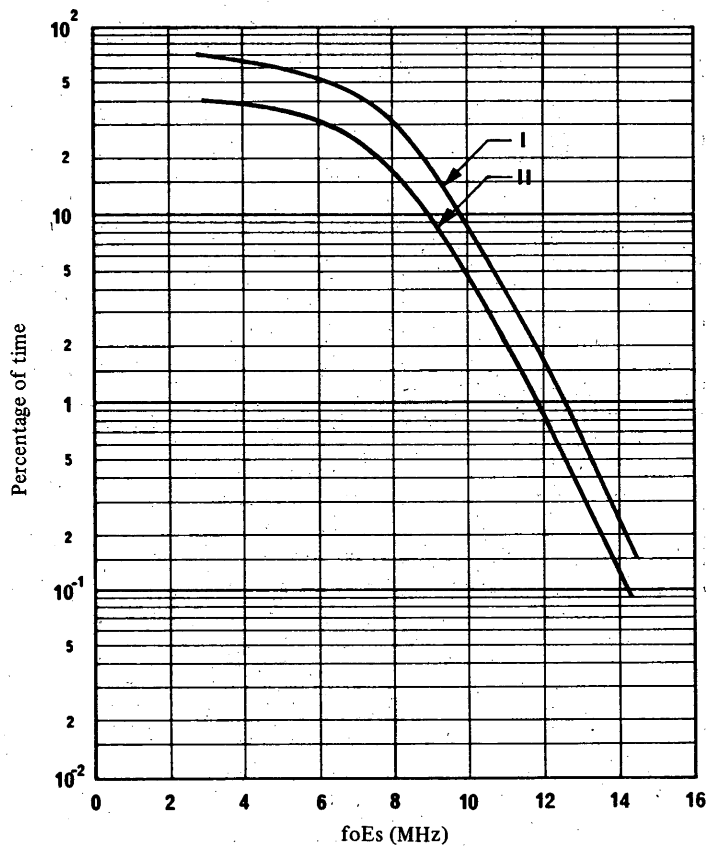

FIGURE 18 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region F: Equatorial Africa (±6° dip latitude)
I: annual average (0600-1800 h)
II: annual average

Note. – Differences between seasons are smaller than the annual average error. Also there is no significant change with solar activity.

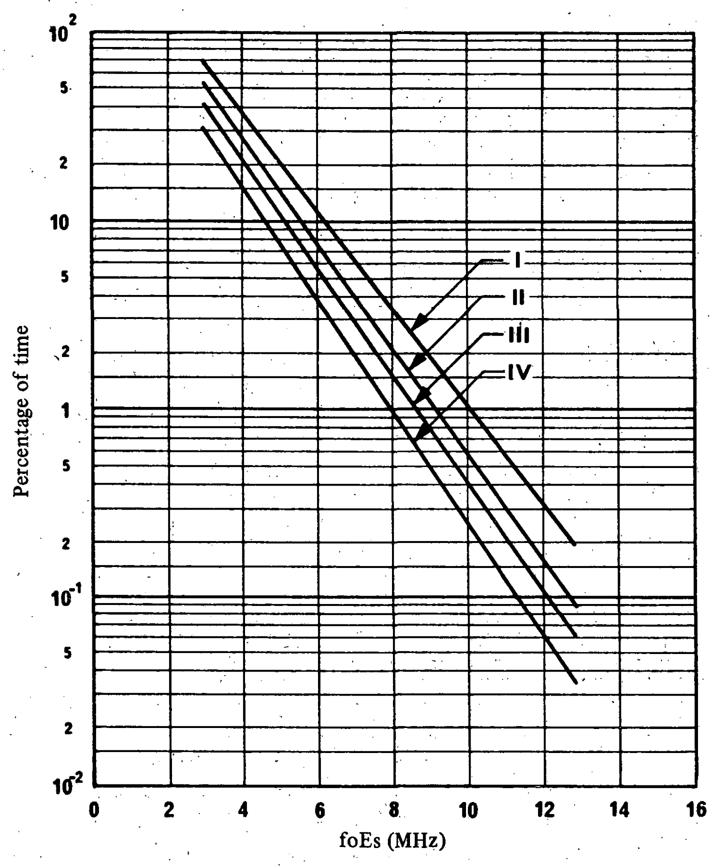

FIGURE 19 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region F: Sub-equatorial Africa (between ±6° and ±20° dip latitude)
I: summer (0600-1800 h)
II: summer
III: annual average and equinox
IV: winter

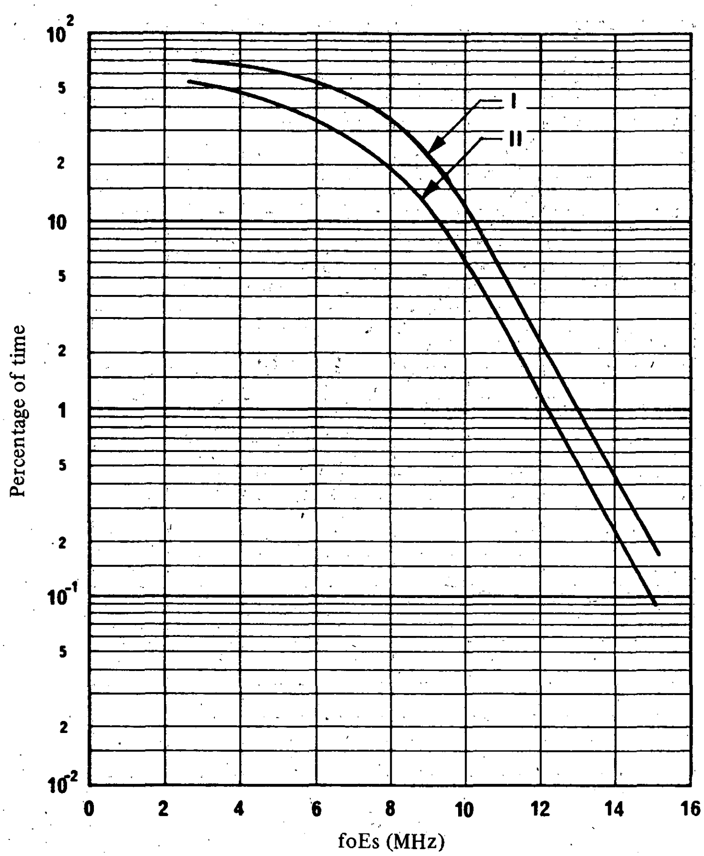

FIGURE 20 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region G: Equatorial America (±6° dip latitude)
I: annual average (0600-1800 h)
II: annual average

Note. – Differences between seasons are smaller than the annual average error.

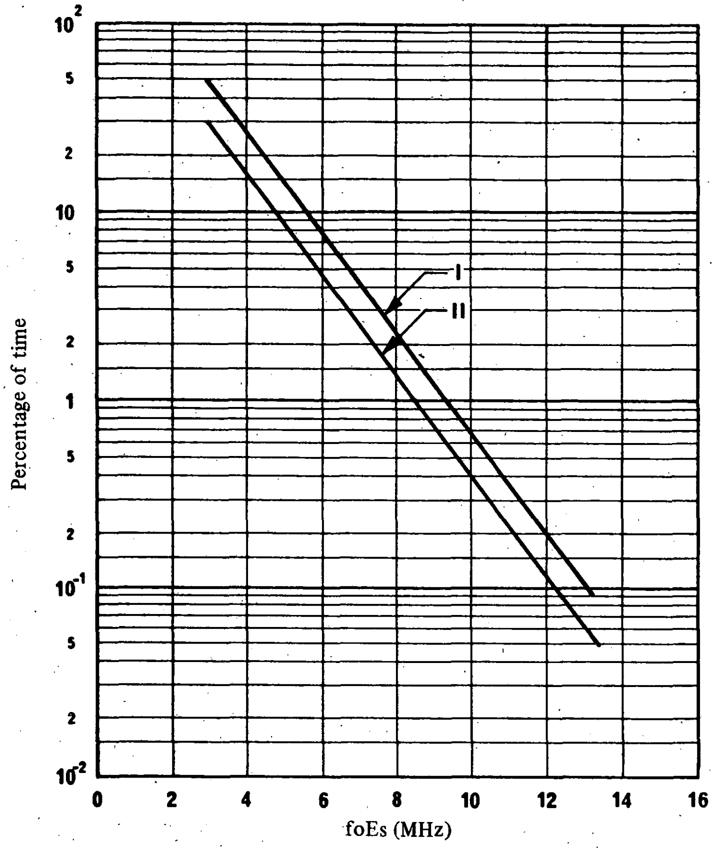

FIGURE 21 – *Values of foEs equalled or exceeded for indicated percentage of time*

Region G: Sub-equatorial America (between ±6° and ±20° dip latitude)
I: annual average (0600-1800 h)
II: annual average

Note. – Differences between seasons are smaller than the annual average error.

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SECTION 6G: IONOSPHERIC PROPAGATION MEASUREMENTS AND DATA BANKS

There are no Recommendations in this Section.

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RESOLUTIONS AND OPINIONS

RESOLUTION 4-4

DISSEMINATION OF BASIC INDICES FOR IONOSPHERIC PROPAGATION

(1963-1966-1974-1986-1990)

The CCIR,

CONSIDERING

(a) that R_{12}, IG_{12} and Φ_{12} have been recommended as indices for use in ionospheric propagation (see Recommendation 371);

(b) that it is desirable to make available to administrations the most recent observed and predicted values of these indices,

UNANIMOUSLY DECIDES

1. that the Director, CCIR, should be requested:

1.1 to make arrangements to obtain the monthly mean value of Φ, and the necessary solar and ionospheric data needed for calculating monthly values of the indices R_{12} and IG_{12};

1.2 to have these indices published in the *Telecommunication Journal* together with any predictions of the indices which can be made available by organizations and administrations;

1.3 to consider making these indices available within computer-based bulletins which can be interrogated in real time through international telecommunication networks by administrations and other interested organizations;

2. that organizations which are at present obtaining basic solar and ionospheric data useful for the production of these indices should be urged to continue to make the necessary observations and to forward them to the Director, CCIR.

RESOLUTION 63-3*

COMPUTER PROGRAMS FOR THE PREDICTION OF IONOSPHERIC CHARACTERISTICS, SKY-WAVE TRANSMISSION LOSS AND NOISE

(1978-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that methods of prediction of the state of the ionosphere and of radio-wave propagation characteristics are given in Reports of the CCIR;

(b) that for effective use of such methods computer programs and associated reference numerical data are needed;

(c) that it is uneconomic for individual organizations to develop their own computer programs for these predictions,

UNANIMOUSLY DECIDES

1. that the Director, CCIR, should be requested to:

1.1 invite organizations which at present have their own computer programs, numerical reference data, and related documentation for the prediction methods described in Study Group 6 Reports and Recommendations, to consider the possibility of making these available to the CCIR Secretariat through Study Group 6;

1.2 prepare computer programs in standardized language (if they do not already exist), together with numerical data and appropriate documentation (referencing specifically the version of the relevant Report);

1.3 make these available for distribution/sale to member administrations and others;

1.4 prepare and publish lists of available computer programs and numerical reference data in appropriate CCIR documents and in the Telecommunication Journal, together with supporting technical descriptions and examples.

ANNEX I

LIST OF COMPUTER PROGRAMS AVAILABLE FROM THE CCIR SECRETARIAT BASED ON PREDICTION METHODS DESCRIBED IN STUDY GROUP 6 REPORTS AND RECOMMENDATIONS

1. CCIR HF propagation prediction method (Report 894):

– third CCIR computer-based method for estimation of MUF, sky-wave field strength, signal/noise ratio, LUF and basic circuit reliability.

The associated program, REP894-2, based on Report 894-2 (Düsseldorf, 1990), is available for mainframe and microcomputer application.

2. CCIR interim method for estimating sky-wave field strength and transmission loss at frequencies between the approximate limits of 2 and 30 MHz (Report 252):

– prediction of transmission loss and field strength.

The associated program, HFMLOSS, is available for mainframe application.

3. Second CCIR computer-based interim method for estimating sky-wave field strength and transmission loss at frequencies between 2 and 30 MHz (Supplement to Report 252):

– a more advanced method for the prediction of transmission loss and field strength.

The associated program, SUP252, is available for mainframe application.

* This Resolution is brought to the attention of Study Group 1.

4. Characteristics and applications of atmospheric radio noise data (Reports 322-2 (Geneva, 1982) and 322-3 (Dubrovnik, 1986)) and man-made radio noise (Report 258):

– prediction of noise power and field strength at any frequency above 10 kHz for any geographic location and time.

The program relating to Report 322-2, NOISEY, is available for mainframe application; that relating to Report 322-3, NOISEDAT, is for microcomputer application.

5. CCIR atlas of ionospheric characteristics (Report 340):

– prediction for any geographic location at a series of times, and for a series of locations at any time, of:
  (a) median foF2 (Oslo numerical coefficients)
  (b) median foF2 (New Delhi numerical coefficients)
  (c) median M(3000)F2
  (d) median foE
  (e) median foF1
  (f) median, upper decile and lower decile foEs – sunspot maximum and minimum
  (g) median, upper decile and lower decile fbEs – sunspot minimum
  (h) median h'F – sunspot maximum and minimum
  (j) median h'F,F2 – sunspot maximum and minimum
  (k) percentage occurrence of spread F – sunspot maximum and minimum
– prediction for any propagation path and time of E- and F-layer basic and operational MUF.

The associated programs, MUFFY, HRMNTH and WOMAP are available for mainframe application.

6. Simple method for estimating basic MUF and HF field strength:

The associated program, MINIFTZ, is available for use on small microcomputers.

Note 1 – The programs available for mainframe application are written in FORTRAN 4 on FORTRAN 77 and are IBM compatible. The program described in item 1 is supplied on diskette and those described in items 2 to 5 are available on magnetic tape with the following characteristics:

– 9 track,
– code: EBCDIC *or* ASCII/ISO 7,
– density: 800 *or* 1600 BPI,
– labelled *or* unlabelled (usually unlabelled),
– record length: fixed (preferably 80 characters) *or* variable.

Preferred options should be specified when placing a purchase order with the CCIR.

Note 2 – The programs for microcomputer application are available on 360 kB or 1.2 MB 5 1/4 inch diskettes (MS-DOS).

Note 3 – For further details involving the methods given in Report 894, Report 252 and Supplement to Report 252, see Recommendation 533.

ANNEX II

NUMERICAL REFERENCE DATA AVAILABLE FROM CCIR FOR USE IN PREDICTION METHODS LISTED IN ANNEX I

Some of the prediction methods listed in Annex I require certain reference data. These data are available on magnetic tape or floppy disk for mainframe computer application or on floppy disk only for microcomputer evaluation. There are three magnetic tapes, referred to as Data Tapes 1-3. The separate tapes have been prepared for use with particular procedures and programs in mind, but since they each contain a number of different sets of data, they may be used in part for other purposes.

Table I lists the data available on each tape and indicates the source documents to which they relate.

TABLE I – *Contents of ionospheric data tapes 1-3*

	Data	Source document	Tape number		
			1	2	3
1	foF2 (Oslo coefficients)	Report 340, Part 2	x		x
2	foF2 (New Delhi coefficients)	Report 340, Part 2		x	
3	M(3000)F2	Report 340, Part 2	x	x	x
4	foE	Report 252	x	x	
5	foEs median and deciles	Report 340, Part 5	x	x	x
6	h'F	Report 340, Part 7	x	x	
7	h'F,F2	Report 340, Part 7			x
8	F_u and F_l	Report 252	x	x	x
9	MUF regression with K	Barghausen *et al.* [1969]	x	x	
10	Excess system loss; median, and standard deviations	Report 252	x	x	
11	Excess system loss; uncertainties	Barghausen *et al.* [1969]	x	x	
12	T_u and T_l	Supplement to Report 252			x
13	Land/sea boundaries	Report 252	x	x	x
14	1 MHz atmospheric noise power (LT representation)	Report 322-2	x		
15	1 MHz atmospheric noise power (UT representation)	Report 322-2		x	x
16	Frequency dependence, decile deviations and prediction uncertainties of atmospheric noise power	Report 322-2	x	x	x
17	Earth's magnetic field	Report 340, Part 2			x
18	Corrected geomagnetic coordinates	Supplement to Report 252			x

The magnetic tape characteristics are the same as those given in Annex I with the exception of the record length which is fixed at 120 characters. A program to convert the tapes to binary format is also available.

There are two disk sets (A and B). Set A contains the binary data needed with the method of Report 894 whilst set B holds in binary or formatted form, all data currently contained on the three data tapes.

Table II lists the data available on each disk set and indicates the source documents to which they relate.

TABLE II – *Contents of data disk sets A and B*

	Characteristic	Source document	Disk set A	Disk set B
1	foF2 (Oslo coefficients)	Report 340-6, Part 2	x	x
2	foF2 (New Delhi coefficients)	Report 340-6, Part 2		x
3	foEs median and deciles	Report 340-6, Part 6		x
4	M(3000)F2	Report 340-6, Part 2	x	x
5	foE	Report 340-6, Part 4		x
6	h'F (Set 1)	Report 340-6, Part 8		x
7	h'F (Set 2)	Report 340-6, Part 8		x
8	h'F,F2	Report 340-6, Part 8		x
9	F_u and F_l	Report 252-2		x
10	Excess system loss median, and standard deviations	Report 252-2	x	x
11	T_u and T_l	Supplement to Report 252-2		x
12	1 MHz atmospheric noise power (UT representation)	Report 322-2		x
13	1 MHz atmospheric noise power (LT representation)	Report 322-2		x
14	1 MHz atmospheric noise power (LT representation)	Report 322-3	x	x
15	Frequency dependence, decile deviations and prediction uncertainties of atmospheric noise power	Report 322-3	x	x
16	Land/sea boundaries	Report 252-2		x
17	Earth's magnetic field	Report 340-6, Part 2		x
18	Corrected geomagnetic coordinates	Supplement to Report 252-2		x
19	Excess system loss uncertainties	Barghausen *et al.* [1969]		x
20	MUF regression with K	Barghausen *et al.* [1969]		x

The floppy disk characteristics are as given in Annex I. For formatted data the maximum record length is 80 bytes. The number of disks involved depending on disk capacity is indicated in Table III.

TABLE III — *Number of floppy disks*

Disk capacity	Disk set A	Disk set B	
		(Binary)	(Formatted)
360 kbytes	1	4	14
1.2 Mbytes	1	1	4

A program to convert the formatted data of set **B** into binary form is also available.

Further details of the contents of the data tapes, disks and associated programs may be obtained from the CCIR Secretariat.

REFERENCES

BARGHAUSEN, A. F., FINNEY, J. W., PROCTOR, L. L. and SCHULTZ, L. D. [1969] Predicting long-term operational parameters of high-frequency sky-wave telecommunication systems. ESSA Tech. Rep. ERL 110-1TS 78, US Govt. Printing Office, Washington, DC.

ANNEX III

DATA BANKS OF FIELD-STRENGTH MEASUREMENTS AVAILABLE ON MAGNETIC TAPE FROM THE CCIR SECRETARIAT

IWP 6/1 has developed data banks of measured HF field strength for further testing of prediction procedures [Bradley, 1985; Suessman, 1989]. Those currently available are as follows:

1. Data Bank C

Comprises measured HF field strengths for 180 combinations of circuit and frequency, with frequencies between 4.8 and 26 MHz and path lengths between 175 and 25 000 km.

2. Data Bank D1

Comprises measured HF field strengths for 181 combinations of circuit and frequency, with frequencies between 2.5 and 26 MHz and path lengths between 175 and 26 000 km.

REFERENCES

BRADLEY, P. A. [1985] New CCIR data base of measured HF field strengths prepared for IWP 6/13. IWP 6/1 Doc. 250.

SUESSMANN, P. [1989] CCIR data bank D1. IWP 6/1 Doc. 331.

ANNEX IV

AVAILABLE COMPUTER IMPLEMENTATIONS OF ANTENNA CHARACTERISTICS (RECOGNIZING THE IMPORTANCE OF CORRECT ALLOWANCES FOR ANTENNA GAIN IN HF PROPAGATION ASSESSMENT)

1. The computation of antenna gain for any direction is included in the program SUP252 for the following types of antenna:

(a) grounded vertical monopole
(b) vertical dipole
(c) horizontal dipole
(d) horizontal terminated rhombic
(e) horizontal log-periodic
(f) horizontal Yagi
(g) curtain array of horizontal dipoles with perfectly conducting screen
(h) terminated sloping-V
(j) terminated sloping rhombic
(k) sloping long wire
(l) inverted L
(m) half rhombic
(n) arbitrarily tilted dipole
(p) sloping double rhombic
(q) loop antennas

2. Microcomputer program packages are available from the CCIR Secretariat for pattern calculation of the following types of antenna:

– HF arrays of half-wave horizontal dipoles (HFARRAYS) and HF horizontal rhombic antennas (HFRHOMBS) (see ITU circulars Nos. 22 and 22 *bis*, 3 December, 1984);

  The HFARRAYS program allows pattern calculation of any type of half-wave horizontal dipole array from the single dipole up to complex curtain antennas at arbitrary height over imperfect ground.

  The HFRHOMBS program allows pattern calculation of horizontal rhombics with arbitrary side length, angle and height over imperfect ground.

– arrays of up to four vertical elements for LF and MF (LFMFANT) (see ITU circulars No. 64, 3 December, 1985 and No. 64 *bis*, 26 June, 1986);

  LFMANT allows pattern calculation of arrays consisting of up to four vertical elements of arbitrary height. Calculation can be performed either for perfect or imperfect ground.

– HF multi-band, slewed or unslewed, horizontal half-wave dipole arrays with aperiodic reflector over imperfect ground (HFMULSLW) (see ITU circular No. 95, 13 August, 1986);

– HF single or dual band, slewed or unslewed, horizontal half-wave dipole arrays with tuned dipole reflector over imperfect ground (HFDUASLW); (see ITU circular No. 95, 13 August, 1986).

  A variation of the HFDUASLW program called HFDUASL1 is also available which performs the pattern calculation for end-fed dipole antenna arrays both in slewed and unslewed condition.

ANNEX V

COMPUTER PROGRAMS STILL NEEDED

– method for predicting sky-wave field strength at frequencies between 150 kHz and 1600 kHz (see Annex I) to Recommendation 435);

Note – A computer program has been developed for this method by Inuki *et al.* [1983].

– CCIR method for calculating sporadic-E field strength (Annex I to Recommendation 534);

Note – A computer program has been developed for this method by IWP 6/8 [CCIR, 1986-90].

REFERENCES

INUKI, H., WAKAI, N. and KURIKI, I. [September, 1983] Development of the computer program for predicting LF and MF sky-wave field strengths (in Japanese). *Rev. Radio Res. Labs. Japan*, Vol. 29, **152**, 467-485.

CCIR Documents:

[1986-90]: 6/184 (IWP 6/8).

RESOLUTION 74-1*

DETERMINATION OF SUNSPOT NUMBERS

(1982–1990)

The CCIR,

CONSIDERING

that the Zurich Observatory ceased production of the relative sunspot numbers, R_Z, after 31 December, 1980,

UNANIMOUSLY DECIDES

1. that the Director, CCIR, should be requested:

1.1 to recognize that for CCIR purposes the relative sunspot numbers to be prepared by the Sunspot Index Data Center (SIDC) directed by Dr. A. Koeckelenbergh at the Observatoire de Belgique (Uccle) will continue the former relative sunspot numbers, R_Z, from 1 January 1981. The international relative sunspot numbers are designated R_I;

1.2 to note that the following services which were formerly provided by the Zurich Observatory are being continued by the SIDC:

1.2.1 determination and *prompt* monthly distribution of the *provisional international relative sunspot numbers* to international institutions and services being in need of these data;

1.2.2 determination and distribution of the *predictions of the smoothed monthly international relative sunspot numbers*;

1.2.3 determination and annual distribution of the *definitive international relative sunspot numbers*;

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* The Director, CCIR, is requested to bring this Resolution to the attention of ICSU, URSI and IAU.

RESOLUTION 111

HF FIELD-STRENGTH MEASUREMENT CAMPAIGN

(1990)

The CCIR,

CONSIDERING

(a) that the WARC HFBC-87 in its Recommendation No. 514 (HFBC-87) invites the CCIR to undertake studies of the HF propagation prediction method adopted by the Conference and to recommend both improvements in the method and later, if necessary, an improved method to be used in the future for the HF bands allocated exclusively to the broadcasting service;

(b) that significant improvements seem unlikely until a substantial data base of new measurements becomes available;

(c) that Report 1149 proposes a field-strength measurement campaign and identifies a need for coordination, training etc;

(d) that Recommendation No. 514 (HFBC-87) also recommends administrations:

– to conduct HF field-strength measurement programmes;

– to contribute data, in a form suitable for study, to the CCIR;

(e) that Decision 84 indicates that attempts to conduct a one-year measurement campaign should be discontinued but that administrations should be urged to undertake such measurements in the longer term,

UNANIMOUSLY DECIDES

1. that administrations should be urged to assist in the campaign by providing transmissions from at least nine locations world-wide and by installing and operating, as far as possible, receiving stations world-wide;

2. that the measurement campaign should extend, if possible, through a complete solar cycle but that transmissions on fewer than five frequencies from one location would still provide a valuable facility for measurements;

3. that the Director, CCIR, should coordinate the overall activity and disseminate the information necessary for initiating and running the campaign;

4. further, that the Director, CCIR, should arrange for the receipt of data on computer diskettes, for the validation and incorporation into a data bank of the measurements;

5. that administrations, the Director, CCIR, and other organs of the ITU, in so far as resources allow, should ensure that guidance and training in the installation and operation of measurement stations is provided where required.

RESOLUTION 112

CCIR STUDY GROUP 6 REPORT TO THE WARC HFBC(93)

(1990)

The CCIR,

CONSIDERING

(a) that Recommendation No. 514 of HFBC-87 invites the CCIR to undertake studies of the HF propagation prediction method adopted by the Conference and to recommend both improvements in the method and later, if necessary, an improved method to be used in the future for the HF bands allocated exclusively to the broadcasting service;

(b) that IWP 6/1 is currently undertaking such studies (see Decision 85);

(c) that the report of the work should be submitted to WARC HFBC(93) in time for the IFRB to take account of the results,

UNANIMOUSLY DECIDES

that the Director, CCIR, shall submit the report of studies within Study Group 6 to administrations and to the IFRB 16 months prior to the date of commencement of WARC HFBC(93).

OPINION 22-5

ROUTINE IONOSPHERIC SOUNDING

(Study Programme KA/6)

(1966-1970-1974-1978-1986-1990)

The CCIR,

CONSIDERING

(a) that the routine observations from the existing ground-based ionosonde network together with satellite and oblique sounding programmes provide the bases for continuing improvements in both long- and short-term ionospheric predictions;

(b) that the increasing importance of space research and Earth-space communications will require continued collection of such information, derived as a matter of routine, together with possible increases and changes in the quantity and nature of the information;

(c) that URSI Commission G has formed an Ionosonde Network Advisory Group (INAG) which is responsible for advising ionospheric sounding stations on scientific questions and for advising URSI on questions concerning the network as a whole,

IS UNANIMOUSLY OF THE OPINION that administrations should make every effort:

1. to continue the operation of the ionosonde network and the interchange, preferably in digital form, of basic data, for which there is much demand, through the World Data Centres;

2. to establish new ionosondes at, or transfer existing ionosondes to, places recommended by the CCIR in fulfilment of Study Programme KA/6 or to support the organizations responsible for new and relocated ionosondes;

3. to consult URSI (INAG) on all questions relating to the establishment or closure of stations in the ionosonde network and proposed changes in the programme of operation or analysis of the ionograms;

4. to support the work under Study Programme KA/6 concerning the use of ionospheric data from satellite programmes and to explore the use of such data as are now available at the World Data Centres, for ionospheric predictions.

Note – The Director, CCIR, is requested to transmit the text of this Opinion to the International Union for Radio Science (URSI), the International Union for Geodesy and Geophysics (IUGG), the Special Committee for Solar-Terrestrial Physics (SCOSTEP), the Scientific Committee for Antarctic Research (SCAR) and the Committee for Space Research (COSPAR) for comments.

OPINION 23-4*

OBSERVATIONS NEEDED TO PROVIDE BASIC INDICES FOR IONOSPHERIC PROPAGATION

(Study Programme 26A/6)

(1966-1970-1974-1982-1986)

The CCIR,

CONSIDERING

(a) that IG_{12} is recommended as the index to be used for predicting monthly median values of foF2 for dates, certainly up to 6 months, and perhaps up to 12 months ahead of the date of the last observed value of IG;

(b) that Φ is recommended as the index to be used for predicting monthly median values of foE, foF1 and foF2, for dates, certainly up to 6 months, and perhaps up to 12 months ahead of the date of the last observed value of Φ.

(c) that the 12 month running mean sunspot number R_{12} is recommended as the index to be used for all ionospheric predictions for dates more than 12 months ahead of the date of the last observed value.

IS UNANIMOUSLY OF THE OPINION

1. that the following thirteen long-established ionospheric observing stations (or suitable replacements) be encouraged to continue in operation for the production of the index IG_{12}:

Canberra	College	Johannesburg	Port Stanley
Christchurch	Delhi	Moscow	Slough
Churchill	Huancayo	Mundaring	Tokyo
			Wallops Island

2. that the National Research Council (NRC), Ottawa (Canada) should be encouraged to continue the 10.7 cm solar radio-noise flux measurements necessary for determination of the index Φ;

3. that the Sunspot Index Data Centre (SIDC) directed by Dr. A. Koeckelenbergh, sponsored by the Observatoire Royal de Belgique and the Institut d'Astronomie of the Université libre de Bruxelles, be encouraged to continue determination and distribution of the international relative sunspot numbers.

* The Director, CCIR, is requested to bring this Opinion to the attention of SIDC, NRC and URSI.

OPINION 45-3

EVALUATION OF THE CCIR HF PROPAGATION PREDICTION METHODS

(Study Programme 30A/6)

(1974-1982-1986-1990)

The CCIR,

CONSIDERING

that the method in Report 894 is recommended for use,

IS UNANIMOUSLY OF THE OPINION

1. that administrations and organizations should evaluate this method according to their needs;

2. that administrations and organizations should report their evaluations to the Director, CCIR, for the use of Interim Working Party 6/1.

Note – See also Opinion 68 and Recommendation 533.

OPINION 67

GEOPHYSICAL AND SOLAR OBSERVATIONS NEEDED FOR SHORT-TERM FORECASTING OF IONOSPHERIC PROPAGATION

(Study Programme 27A/6)

(1982)

The CCIR,

CONSIDERING

that the efficient utilization of radio frequencies depends upon the availability of the most reliable world-wide solar-geophysical data obtained by both ground-based and satellite-based observations,

IS UNANIMOUSLY OF THE OPINION that Administrations should make every effort:

1. to make routine observations (such as those discussed in Reports 727 and 888) as a part of world-wide networks, to provide the basis for short-term forecasts;

2. to establish new facilities for making observations in those areas where an adequate network of observation stations does not exist.

Note – The Director, CCIR, is requested to transmit this text together with Reports 727 and 888 to the International Union for Radio Science (URSI), the International Union for Geodesy and Geophysics (IUGG), the International Astronomical Union (IAU), the Scientific Committee for Solar-Terrestrial Physics (SCOSTEP) and the Committee for Space Research (COSPAR) for comment.

OPINION 68-1

DATA BANK OF HF SKY-WAVE SIGNAL INTENSITY MEASUREMENTS

(Question 42/6)

(1982-1990)

The CCIR,

CONSIDERING

(a) that observations of HF sky-wave signal intensity collected under standardized conditions are needed for a wide range of path and operating conditions in order to test the accuracy of methods of signal intensity estimation and to enable the development of new methods;

(b) that Report 253 gives details of how observations may be carried out and reported in order to produce standardized data of the greatest value;

(c) that Report 1149 gives specifications for a field-strength measurement campaign intended for future improvements in prediction methods;

(d) that the CCIR has established through its Interim Working Party 6/1 a data bank of measurements but that the amount of data therein is insufficient for the purposes in hand,

IS UNANIMOUSLY OF THE OPINION

1. that administrations and organizations should make every effort to provide such measured data as exist to the Director, CCIR, for inclusion in the data bank;

2. that administrations and organizations should collect and provide new data in accordance with the details given in Report 253;

3. that, although data in accordance with Report 253 are preferable, administrations and organizations having other data are encouraged to provide them. The nature and method of processing the data should be adequately explained.

Note – See also Opinion 45.

OPINION 69

FIELD-STRENGTH MEASUREMENTS FOR FREQUENCIES BELOW ABOUT 1.7 MHz

(Study Programme 31D/6)

(1982)

The CCIR,

CONSIDERING

that there is a need for improved propagation data at frequencies below about 1.7 MHz,

IS UNANIMOUSLY OF THE OPINION

1. that administrations and organizations which can make field strength and phase measurements, or which can provide suitable transmissions, should be encouraged to participate in measurement campaigns, especially in those parts of the world where few measurements have been made;

2. that administrations and organizations should communicate their results to the Director of the CCIR. The standardized form described in Opinion 46 should be used where possible.

OPINION 82

USE OF AN IONOSPHERICALLY DERIVED SOLAR ACTIVITY INDEX (IG) FOR THE PREDICTION OF foF2

(1986)

The CCIR,

CONSIDERING

(a) that Report 340 contains comprehensive charts and numerical data which afford the most widely available means of predicting foF2, in terms of sunspot numbers;

(b) that the resulting predictions suffer from undesirably large errors in some geographical areas and at some times (see Report 430), and that a prediction system giving improved accuracy would be beneficial to efficient communications;

(c) that the index IG [Liu *et al.*, 1983] which is an ionospherically-based index, derived independently of sunspot number, has been proposed for use with the existing data of Report 340;

Note. – In the above-referenced paper the new index, which is called IG in the present document, is denoted by GESSN.

(d) that evidence has been produced that a useful improvement in accuracy is obtainable in the prediction of foF2 by the use of IG_{12} instead of R_{12};

(e) that monthly values of IG for the past 40 years are available, and that predictions of future values of IG_{12} are being made by the same method as that used for the prediction of R_{12} (see Recommendation 371);

(f) that predicted values of IG_{12} over a sunspot cycle are available from the CCIR Secretariat,

IS UNANIMOUSLY OF THE OPINION

that the Science and Engineering Research Council of the United Kingdom should be encouraged to continue the prediction of IG_{12} for the estimation of foF2, and to send the predictions to the Director, CCIR, for the use of administrations and organizations requiring them.

REFERENCES

LIU, R. Y., SMITH, P. A. and KING, J. W. [1983] A new solar index which leads to improved foF2 predictions using the CCIR Atlas. *Telecomm. J.*, Vol. 50, **VIII**, 408-414.

OPINION 85*

MEASUREMENTS OF THE CHARACTERISTICS OF ATMOSPHERIC RADIO NOISE

(1986)

The CCIR,

CONSIDERING

(a) that the intensity of atmospheric radio noise sets a limit to the performance of radio circuits operating at frequencies below about 30 MHz;

(b) that information contained in Report 322-2 (Geneva, 1982) has been used for many years as an element in the planning of radio services;

(c) that Report 322-3 provides new information on the characteristics of atmospheric radio noise which, for some parts of the world, differs considerably from that in the earlier version of the Report;

(d) that further studies are necessary as detailed in Study Programme 29B/6;

IS UNANIMOUSLY OF THE OPINION that administrations and recognized private operating agencies should make every effort:

1. to make measurements of the intensity and other characteristics of atmospheric radio noise, bearing in mind the need to distinguish natural noise from that due to man-made sources;

2. to analyse the results of measurements of atmospheric radio noise in terms of the parameters used in Report 322 so as to facilitate comparison;

3. to evaluate the practical effects of applying the information of Report 322 to the planning of radio systems.

* This Opinion should be brought to the attention of Study Groups 1, 3, 7, 8 and 10.

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