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INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

**DOCUMENTS OF THE
IXth PLENARY ASSEMBLY**

LOS ANGELES, 1959

VOLUME III

REPORTS



Published by the
INTERNATIONAL TELECOMMUNICATION UNION
GENEVA, 1959

INTERNATIONAL RADIO CONSULTATIVE COMMITTEE



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Corrigendum to Volume III - issued in April 1960

Volume III

p. 7, last paragraph.

p. 12 Rep. 114, title.

p. 103 Rep. 90, § 1, line 1.

p. 117 Rep. 115, § 17.

p. 123 Rep. 115, Fig. 3, title.

p. 169 Rep. 124, Table III (continued), title.

p. 204 Rep. 134, § 2.10 and § 2.14.

p. 207 Rep. 135, Part 1, § 1.3, line 4.

p. 208 Rep. 135, Part 2, line 4.

p. 224 Rep. 65, § 2, par. 5.

p. 390 Rep. 166, Notes 21 and 22.

p. 392 Rep. 166, Annex III, beneath map.

Replace "VIIIth Plenary Assembly, (Warsaw, 1956)" by "IXth Plenary Assembly, (Los Angeles, 1959)".

Replace "maritime" by "land".

Replace "471" by "471 of Warsaw, 1956".

Replace "48 000" by "480 000".

Replace "48 000" by "480 000".

Replace "810" by "819".

Replace "commander" by "compandor".

Replace "292" by "287".

Replace "292" by "287".

Replace formula by

$$E_n = F_a - 65 \cdot 5 + 20 \log_{10} f$$

Replace "further" by "subsequently".

Replace "2-5 Mc/s" by "2.5 Mc/s (ZLFS)".

May, 1961

Corrigendum to Volume III - issued in May 1961

Volume III

Page 170, Rep. 124, Table III, Note 4, delete "from 0.15 to 0.51H " substitute "from 0.015 to 0.515H ".

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Note. — For ease of reference the page numbering in the English and French editions has been made the same.

LAYOUT OF VOLUMES I, II AND III

(Recommendations, Reports, Resolutions, Questions and Study Programmes of the C.C.I.R.)

General

The Recommendations, Reports, Resolutions, Questions and Study Programmes of the C.C.I.R., the texts of which appear in Volumes I, II and III, are those which have been approved by the IXth Plenary Assembly of the C.C.I.R., together with those which, approved by the Vth, VIth, VIIth and VIIIth Plenary Assemblies, have been retained.

The Recommendations, Reports and Resolutions of a general nature are arranged in numerical order.

The Questions and Study Programmes are grouped together and arranged in the numerical order of the Study Groups. For each Study Group the Questions are laid out in numerical order, each being followed by the Resolution(s) and Study Programme(s) to which they are related. Study Programmes which are not the result of a Question are indicated by a note.

Questions submitted to the C.C.I.T.T. form the subject of a separate chapter.

References to the texts, if any, forming the basis of Recommendations, Reports, Resolutions, Questions and Study Programmes are given below the title. On the right under this reference is shown the Plenary Assembly or Assemblies which have approved or subsequently modified the text.

Mention is made in a footnote, when the occasion arises, of the texts or text which have been replaced by the text in question; in the case of a Question, the Study Programmes are shown which arise from it; and in the case of Study Programmes, mention has been made where necessary of the Questions to which they refer.

To facilitate reference to a desired document, and to reduce the bulk of the bound edition, the previous Volume I has been divided into three:

Volume I : Recommendations of the C.C.I.R.

Volume II : Resolutions, Questions and Study Programmes of the C.C.I.R.

Volume III : Reports of the C.C.I.R.

Further to facilitate the tracing of a desired document, the Recommendations and Reports of the C.C.I.R., while retaining their serial numbering, have been grouped into ten sections designated by capital letters:

A. Transmission	F. Radio-relay systems
B. Reception	G. Propagation
C. Fixed services	H. Standard-frequencies and time signals
D. Mobile services and space-systems	J. International monitoring
E. Sound broadcasting and television	K. Vocabulary

Definitions of the Recommendations, Reports, Resolutions, Questions and Study Programmes of the C.C.I.R.

The following definitions of Recommendations, Resolutions and Questions are those which appear in Doc. No. 272 of Geneva (Drafting Committee). The definition given for Study Programmes is that which appears in Doc. No. 630 of London (Drafting Committee). The definition given for Reports is that which appears in Doc. No. 731 of London (U.S.A.) modified by the addition of the words "by a Study Group".

Recommendation	Statement issued when the study of a Question, or part of a Question, has been concluded.
Report	Statement for information, on the studies carried out by a Study Group on a given subject.
Resolution	Statement of an opinion of the C.C.I.R. on a non-technical subject.
Question	Statement of a technical problem which the C.C.I.R. is to consider.
Study Programme	Text describing the work to be done on a given technical problem forming the subject of a Question.

Origin of certain documents referred to in these volumes

The documents referred to in these volume as "Stockholm", "Geneva", "London", "Warsaw" and "Los Angeles" are respectively the documents of the Vth, VIth, VIIth, VIIIth and IXth Plenary Assemblies of the C.C.I.R. held in Stockholm in 1948, Geneva in 1951, London in 1953, Warsaw in 1956 and Los Angeles in 1959.

The documents referred to in these volumes as "Mexico" and "Florence/Rapallo", are respectively those of the High-Frequency Broadcasting Conferences of Mexico City in 1948-49 and of Florence/Rapallo in 1950.

Other documents referred to in these volumes are the documents of the meetings of certain Study Groups of the C.C.I.R. The following list of the meetings of these Study Groups is given for information:

Zurich (July 1949)	Study Group No. XI
Washington (March 1950)	Study Groups Nos. VI and X
London (May 1950)	Study Group No. XI
Geneva (July 1950)	Sub-Group Gerber of Study Group No. XI
The Hague (April 1952)	Study Groups Nos. I and III
Stockholm (May 1952)	Study Groups Nos. V, VI and XI
Geneva (August 1952)	Study Group No. X
Geneva (September 1952)	Study Group No. IX
Brussels (March-April 1955)	Study Groups Nos. I and XI
Paris (July 1957)	C.M.T.T. (Joint Study Group for television transmission)
Geneva (December 1957)	Sub-Group Lépéchinsky
Moscow (May-June 1958)	Study Group No. XI
Geneva (July-August 1958)	Study Groups Nos. I, II, III, IV, V, VI, VII & IX
Monte-Carlo (October 1958)	C.M.T.T.

Numbering of the Recommendations, Reports, Resolutions, Questions and Study Programmes of the C.C.I.R.

The Recommendations, Reports, Resolutions, Questions and Study Programmes of the C.C.I.R. are numbered consecutively in five series, each starting at No. 1.

The series of Recommendations, Questions and Resolutions were started at the Vth Plenary Assembly (Stockholm, 1948).

The series of Reports and Study Programmes were started at the VIth Plenary Assembly (Geneva 1951).

Questions and Study Programmes remaining for study after the VIIIth Plenary Assembly (Warsaw, 1956) carry in Roman figures after the serial number, the number of the Study Group to which they have been submitted.

The following table serves as a guide to the numbering of C.C.I.R. documents:

Plenary Assembly of C.C.I.R.	Recommendation No.	Report No.	Resolution No.	Question No.	Study Programme No.
Vth Stockholm (1948)	1 to 35	Nil	1 & 2	1 to 33*	Nil
VIth Geneva (1951)	36 to 85**	1 to 15	3 to 9	46 to 73	1 to 38
VIIth London (1953)	87 to 144	16 to 37	10 to 19	74 to 112***	39 to 78***
VIIIth Warsaw (1956)	145 to 227	38 to 95	20 to 38	123 to 164****	82 to 115****
IXth Los Angeles (1959)	228 to 324	96 to 174	39 to 67	171 to 206	124 to 168

* Questions Nos. 34 to 45 were submitted to the C.C.I.R. between the Vth and VIth Plenary Assemblies.

** Recommendation No. 86 was issued after the meeting of Study Group X of the C.C.I.R. held at Geneva 1952.

*** Questions Nos. 113 to 122 and Study Programmes Nos. 79 to 81 were submitted to the C.C.I.R. between the VIIth and VIIIth Plenary Assemblies.

**** Questions Nos. 165 to 170 and Study Programmes Nos. 116-123 were submitted to the C.C.I.R. between the VIIIth and IXth Plenary Assemblies.

NOTE BY THE DIRECTOR OF THE C.C.I.R.

Adoption of the Reports contained in this Volume

1. Unless otherwise indicated, the Reports contained in this Volume were adopted during the course of the Vth (Stockholm), VIth (Geneva), VIIth (London), VIIIth (Warsaw) and IXth (Los Angeles) Plenary Assemblies of the C.C.I.R. A note at the foot of the page on which each Report begins, indicates whether the Report was adopted unanimously or whether certain countries had formulated reservations regarding its contents.

2. In addition to the Reports mentioned above, this Volume also contains Reports which were prepared during the course of the IXth Plenary Assembly (Los Angeles, 1959) and were examined by the Drafting Committee, but, through lack of available time, were not presented for approval at a Plenary Meeting.

The Plenary Assembly decided in the course of its eleventh meeting (see Volume V of the Documents of the IXth Plenary Assembly, Report of the eleventh Plenary Meeting §6, and Doc. No. 734 of Los Angeles) that these Reports should be distributed by the Director to Administrations for their comments in time for the replies to reach the Director by 31 July, 1959. These Reports were so distributed by the Director of the C.C.I.R. on 27 June, 1959, and the 22 Administrations who replied made no reservations to the following Reports:

Nos: 96, 97, 99, 100, 105, 106, 107, 110, 111, 112, 124, 125, 127, 128, 129, 130, 131, 132, 133, 135, 136, 138, 139, 140, 142, 143, 145, 146, 147, 149, 153, 154, 158, 159, 160, 166, 168, 169, 170.

The following Reports were the subject of Reservations on the part of the Administrations indicated:—

Nos: 109 (U.K.), 171 (Bielorussia, Ukraine, U.S.S.R.), and 173 (U.K., U.S.A.).

The adoption of each of these Reports is indicated by a note at the foot of the page on which the Report begins.

3. The Director of the C.C.I.R. would like to take this opportunity of thanking the many Administrations who, in addition to their comments on the substance of these Reports, have drawn attention to a number of typographical errors in the texts.
-

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REPORT No. 96 *

POSSIBILITIES OF REDUCING INTERFERENCE AND OF MEASURING ACTUAL TRAFFIC SPECTRA

(Questions Nos. 1 (I) and 133 (III))

(Warsaw, 1956—Los Angeles, 1959)

Summary

Any actual signal which has passed through a quadripole can be developed as a series of time-staggered functions. The sole function on which the development is based is the impulse response of the quadripole, representing the shortest elementary signal which can appear at the output of the quadripole. This development helps to show some of the important properties of actual signal spectra useful in the study of interference and the measurement of spectra with analysers:

- (a) Interference can never be zero, for the spectrum of any actual signal cannot be zero in any frequency interval; it can be zero only at discrete frequencies.
- (b) If the receiver subject to interference can be assimilated to a substantially rectangular pass-band quadripole and it is tuned far enough away from the centre of the spectrum, and if the consecutive signal amplitudes are independent and not correlated, the interference merely adds additional noise to the inherent thermal noise of the receiver.
- (c) If the actual signal fulfills the above conditions, its spectrum may be determined by means of an analyser, and reproducible stable results can be obtained if the analyser is followed by a quadratic integrator.
- (d) If the signal does not fulfill these conditions, the measurements will be unstable, both as regards individual measurements made with the same analyser and measurements made with different analysers.

On the other hand, constant and reproducible results are possible, for instance, in telegraphy, if the actual signal is replaced by a periodic signal, and in telephony if the transmitter is modulated with white noise. One obtains in the first case a time spectrum whose envelope is the spectrum of the elementary signal and in the second case a spectrum identical to that of the elementary signal.

- (e) The problem of reducing interference, which is at a first approximation, the problem of reducing out-of-band radiation, reduces to the problem of finding the best elementary signal in this respect.

A first solution, suggested by Shannon's theories, is to give the signal an approximately Gaussian statistical distribution. Speech approaches this condition fairly closely and can therefore easily be filtered, thus introducing little interference outside a certain band. In telegraphy the only way of forming a similar signal is to use many different combinations of elementary signals of different amplitudes.

Gabor, after choosing a particular definition for signal duration and bandwidth showed that the best elementary signal in those respects was a signal having the shape of a Gaussian curve. Such a shape can be approached as closely as required by using multiple-section filters either with a very simple iterative filter section or non-iterative sections, although a large number of sections introduces a signal delay which is the only parameter limiting the practical application of the method. Nevertheless, delays of not more than one word of medium length should be very

* This report which replaces Report No. 38, was adopted by correspondence without reservation (see page 9).

helpful in reducing out-of-band radiation. Delay is apparently inevitable whenever endeavours are made to compress frequencies or to reduce out-of-band radiation.

Many other signal shapes have been proposed but are either less effective or practically infeasible.

Yet the problem of interference can be tackled only by also taking into account the exact nature of the signal and the receiver properties. The total permissible signal distortion is the distortion introduced by the receiver and transmitter considered together. Villepelet showed, that if a given frequency band was occupied by radiocommunications of the same kind, the best way of solving the interference problem was to allocate one-half of the quadripole representing the system to the transmitter and one-half to the receiver, the receiver and transmitter thus becoming equally selective. Contrary to what might be thought, this principle could be applied in practice in a fairly large number of cases, though it is not followed as a general rule, receivers being nearly always more selective than transmitters.

The theory for circuits having different natures and working on adjacent channels is much more difficult to study and no solution is known, but the problem might be tackled experimentally.

Finally, the receiver might be adapted to the interference so that it should not only be able to receive the wanted signal but also should be highly insensitive to some kinds of interference. Little work has been done along these lines so far, but a general method of studying the problem has been proposed.

1. Introduction — Possible ways of examining interference problems.

The number of radio channels which can be used in a given frequency band depends essentially on the spacing required between adjacent channels. Leaving aside various phenomena and circumstances which necessitate an increase in spacing, such as field fluctuations, the minimum spacing is determined by the interference produced by each channel in neighbouring channels. If the bandwidth occupied by the emissions, and consequently the out-of-band powers as defined in Recommendation No. 230 were known, it would then be possible roughly to determine the minimum necessary spacing between two frequency assignments. But, without knowledge of additional data, such as the rate of decrease of the energy outside the band limits, the power definition of the occupied bandwidth is not sufficient for the purpose of determining channel spacing.

It is hence necessary to deal with the interference problem in a more direct and precise manner; the first problem to be solved is the reduction of the energy of a given emission outside a certain band, and the next is the increase in the slope of the spectrum outside its central part.

Even this does not suffice, for interference cannot be entirely determined by power considerations. It is closely connected with the exact nature of the interfering emission, as well as with the nature of the emission suffering from interference and the characteristics of the receiver. When the problem is thus stated in its entirety, it is very complex and is not generally possible to take all the factors fully into account. Hence it is necessary to use simple and fairly general examples on the basis of which it is possible to reach approximate conclusions and indicate improved procedures with reasonable confidence, after comparing the upper interference limits in the various cases.

In general, interference is produced by emissions transmitting actual information which is not known beforehand. Correct methods of representing emissions in the study of these problems should, therefore, enable the signals transmitted to be represented as random quantities.

Analysis of the properties of real signals is made easier if they are represented as series of functions. The use of functions staggered in time is especially useful for showing the random nature of the signals and dealing at the same time with filtering and interference problems.

For all classes of emissions, except those using frequency modulation, a simple relation can thus be established between the output radio signal and the input modulating signal. Consequently, the following considerations and results are not, in general, applicable to frequency modulation.

If the signal to be transmitted consists (as in telegraphy) of a series of discrete voltages, breakdown into a series of functions staggered in time is quite natural. The emission is then fully determined when:

- an elementary signal, which usually takes the form of a pulse modulating a carrier wave, has been defined;
- one of the parameters of the elementary signal (amplitude, frequency, duration, etc.) has been provided with a coefficient which is proportional to the discrete, random voltages of the original signal.

Another case (telephony provides the simplest example) is when the signal is defined by a continuous time function, and here the same procedure may be used, by varying one of the parameters connected with the elementary signal as a function of the continuous parameter defining the signal.

Various forms of signal breakdown are indicated below: the first one, which uses elementary signals that are all identical but are staggered in time and provided with a coefficient of proportionality, is useful for the discussion of problems in which only energy is involved and which are entirely determined by the form of the spectrum of the overall signal, usually representing an entire message.

Another breakdown, with elementary signals staggered both in time and frequency, will be mentioned for it will allow a more precise analysis of the interference problem, taking into account the exact nature of the transmitting and receiving systems.

2. Breakdown of the signal by means of elementary signals staggered in time — Spectrum properties and measurement possibilities.

It was mentioned above that representation of the signal should show the random form of the signal.

However, it is easier to measure the spectrum during transmission of an elementary signal or a periodic signal made up of a regular succession of elementary signals. These simple signal shapes are very convenient for calculation and permit a fairly easy assessment of their effect on a circuit idealizing the receiver subject to interference. The theoretical problems of interference will thus be simplified if a relation can be found between the spectra of random signals and the spectra of simple signals coming from the same transmitter.

Such a relation can easily be found if the actual signal can be represented by a series of functions with constant coefficients, successive functions being obtained by time-staggering a single function representing an elementary signal. To obtain such a signal in practice, the minimum requirement is that the corresponding function should always be zero before a given moment which is the beginning of the transmission. For example, the theoretical original elementary signal could be a narrow rectangular pulse, the successive switching times being separated by intervals equal to the pulse width. The signal is then represented by a series of functions, the coefficients of which equal to its mean value during each elementary interval.

By reducing the width of the pulse, any actual continuous signal can be represented with a root-mean-square error as small as desired. For this it is sufficient for the integral square of the derivative of the signal to be bounded; in physical terms, this means that the signal must represent a finite quantity of information. Some authors have in fact used this integral of the square of the derivative of the signal to measure the amount of detail contained in a real signal particularly in television.*

It will immediately be seen that the Fourier transform or "amplitude spectrum" of a signal expanded in this way is the product of two spectrum functions.

The first function represents the spectrum of the elementary signal; this spectrum does not depend on the information contained in the signal.

The second function might be called the switching spectrum; it depends on the switching instants and on coefficients which themselves contain all the information. In complex terms, this

* This measurement is naturally different from the measurements based on probabilities of the amount of information which can be defined, after Shannon, by using, for instance, the binary unit. It is logical only with certain types of continuous signals, especially the usual type of television signal. Shannon has shown (4, § 29) how the r.m.s. error limits the capacity of a source for transmitting information.



spectrum function is equal to the sum of the vectors whose length is equal to the coefficients and whose phase is proportional to the frequency and the times of switching.

Such an analysis of the signal presents a certain general character in spite of the special form of the rectangular pulses which have been used. If the spectrum is represented as a product of functions, it can be seen that transformation of the signal by a linear quadripole is equivalent to transformation of the elementary pulse only. At the output of the quadripole the transformed signal spectrum is still represented by the product of two functions. The switching spectrum is the same (and hence so are the coefficients of the series of functions representing the transformed signal); the elementary signal spectrum is replaced by the spectrum of this pulse transformed in the quadripole. At the limit, when the pulse width is reduced indefinitely, the transformed pulse tends towards the impulse response of the quadripole. Any signal transformed by a quadripole can, therefore, be expanded as a series of staggered functions, the original function being the impulse response of the same quadripole.

If the signal is received by an apparatus (e.g., the receiver of the correspondent, or the receiver subject to interference, or a spectrum analyser) which integrates the signal during a certain time, the output voltage of this apparatus, at a given frequency, depends on the sum of the corresponding vectors the number of which increases with the integration time. The phases of those vectors, however, are uniformly distributed around the phase circle and under certain conditions their amplitudes, equal to the mean values of the signal during the sampling intervals, are statistically independent, each one being small, with respect to the overall amplitude. It is well known that in this case, particularly according to the theorems of Liapunov and Paul Levy [1], the statistical distribution of the amplitude of the resultant vector tends towards the Rayleigh law, whereas the instantaneous value of the corresponding overall voltage (projection of the vector on to any fixed axis) has a statistical distribution which tends to become Gaussian when the integration time increases indefinitely. This is valid for any random signals, such as those occurring in telephony, or television, the amplitude of which is always bounded.

It is known that continuous signals in practice do not have statistically independent values at instants very near to each other; however, these values become more and more independent as the instants become more distant one from the other. The condition for independence, therefore, means that the chosen sampling instants are sufficiently separated to ensure that the values corresponding to any two successive instants are practically independent, and hence capable of representing entirely different information.

In the case of telegraphy of the usual type, the position is particularly simple. The elementary signal can be the usual unit signal of the telegraphists, the finite duration of which is that of one code unit and the amplitude coefficients are all equal to 0 or 1 with, as a first approximation, an equal probability for these two values at the sampling instants. The problem is then reduced to that of the random walk which was originally studied by Lord Rayleigh. The statistical distribution of the total amplitude and the total instantaneous value still tend towards Rayleigh and Gaussian distributions respectively, which are approached, with a fair degree of approximation for practical purposes, if a fairly small number of components are added.

The effect of the signal on receivers of fairly small bandwidth which integrate the amplitudes or the powers, can be easily assessed when the spectrum of the elementary signal and also the first (in the case of a linear integrator) or the second (in the case of a quadratic integrator) moment of the statistical distribution of the amplitudes are known. These moments show the mean amplitude and the mean power of the signal respectively.

It may be pointed out that receivers with a narrow bandwidth have a large time constant and are thus naturally linear or quadratic integrators. However, practical calculations show that the most selective ordinary receivers and even the most accurate spectrum analysers still have too wide a bandwidth and consequently a time constant that is too small to ensure a good approximation to the moments of the statistical distribution; their output voltage is always fluctuating, in the presence of a random signal, unless they are followed by an indicator with a very high degree of inertia, preferably a quadratic integrator.

However, the switching spectrum is a periodic function of the frequency without a constant term when the switching times are uniformly spaced; the result is that the spectrum has the shape of the elementary pulse spectrum, multiplied by a periodic function which depends mainly on the information transmitted. Considering the part of the spectrum falling within the (not too narrow)

passband of a receiver subject to interference, the average level of the voltage induced in this receiver thus depends primarily on the shape of the elementary pulse spectrum, whatever the time during which the whole receiving system integrates the voltage or the power.

If, instead of considering the Fourier transform of the signal (or amplitude spectrum) we consider the usual spectrum of the physicists, which is a power spectrum, it is possible to specify the preceding properties a little better. It is known that this spectrum is the Fourier transform of the correlation function of the signal. If this signal is represented, as before, by a series of staggered functions, it is found that the spectrum is also the product of two spectrum functions. The first is the (power) spectrum of the elementary signal, and the second the Fourier transform of the correlation function of the original signal. This second spectrum function is reduced to a constant if the correlation function is periodically cancelled out, the period being equal to the time separating two consecutive switching instants. In this case the signal is said to be uncorrelated with the switching or sampling instants (which alone are of interest to us). The spectrum is then identical with that of the elementary signal, apart from a constant coefficient which represents the mean power of the overall signal. The problems of determining interference and measuring the spectrum with a spectrum analyser are then very simple; a quadratic integrator at the output immediately gives the power in the analysed part of the spectrum. With regard to those parts of the spectrum which are fairly distant from the central frequency, where the spectrum of the elementary signal generally varies fairly slowly with frequency, and if the receiver subject to interference or the analyser has a passband which without too much error, may be treated as a relatively narrow rectangular filter they isolate within the spectrum a portion having a constant level throughout their bands, with zero level outside. If then the original signal is not only uncorrelated, but takes independent values at the sampling instants, the signal leaving the analyser, or acting on the terminal apparatus of the receiver subject to interference, is a "white" Gaussian signal, which can be compared in every respect with thermal noise ((3) Chapter XIII, page 513). The sole effect of the interference is then to increase the noise level at the output of the receiver subject to interference. With equal power in a given band, this is the most damaging form of interference since it causes the greatest loss of capacity in the channel under consideration.

If, therefore, we wish to measure easily and rapidly the spectrum emitted by a transmitter which is designed to send out continuous signals (a radiotelephone transmitter, for example), it suffices to apply a thermal noise of suitable power to it, instead of its normal signal. This method, which is indicated in Recommendation No. 145 (§. 2.4) as elsewhere, is the simplest in theory.

If, on the other hand, the signal is correlated, a term depending on the frequency is added to the preceding constant which represents the mean signal power. If, as before, we assume that the receiver subject to interference of the spectrum analyser has a fairly narrow passband, and is tuned at some distance from the central part of the spectrum, it is reasonable to examine especially the effect of the second spectrum function on such apparatus. This effect is represented by a doubly periodic function: it varies periodically when the tuning frequency departs from the central frequency of the signal; it also varies periodically when the bandwidth of the receiver or the analyser varies. Hence, if the signal is correlated, the amount of interference experienced by a receiver and the information provided by a spectrum analyser depend in a complicated way not only on the statistical properties of the signal, but on the characteristics of such apparatus, particularly on the bandwidth; the analysis cannot be followed through to its conclusion unless all the corresponding data are known.

What is always important, however, is the independence of the two spectrum functions, as well as the essential consequence: the spectrum of any signal decreases at the spectrum of the elementary signal defined by the quadrupole through which the signal flows.

In the case of a correlated signal, the collected power simply becomes proportional to the bandwidth of the analyser filter, only if this bandwidth is very narrow (with respect to the reciprocal of the sampling interval). But with a narrow filter, it is necessary to reduce the sweep speed, and even to abandon an automatic sweep, if it is wished to obtain results with a fair degree of approximation from the measurements. With a manual-sweep analyser, the total measurement of the spectrum takes so long that measurements of the different parts of the spectrum are mutually incoherent, even if the analyser is followed by an integrator with a long time constant. This incoherence disappears only if the measurements are carried out by applying periodic signals to the transmitter.



This method always seems preferable for telegraphy, owing to the simple relationships which exist between the spectra of the periodic signals, the spectrum of the elementary signal and the mean spectrum of the random signals emitted by the same system.

Marique has made a fairly rigorous study of the effect of non-periodic telegraph signals on spectrum analysers [2].

These considerations end with a mathematical note which has important practical consequences. The spectrum of an actual signal is represented by an integer function, if (as is always the case in practice), the signal has traversed a passive quadripole. This is because an actual signal is null before the finite instant at which the message begins, is always bounded and after passage through the passive quadripole falls off exponentially towards zero from the moment the message ends.

Hence, whatever real signal is transmitted, we must always consider a spectrum represented by an integer function, that is to say, extending to infinity and cancelling out only at distinct frequencies (which may be an enumerable infinity) but never in a frequency interval, no matter how small it may be.

The rest will perhaps be clearer if we sum up the conclusions we can draw from the above:

- (a) The problem of interference will always exist. Since the spectrum of an actual signal cannot be zero in any frequency interval, any receiver tuned close to the carrier of any actual emission receives energy therefrom. If the frequency difference is large enough, this energy may be small, and sometimes negligible, but it can never be zero.
- (b) The effect of interference on a receiver cannot be assessed if we know merely the energy received from the interfering station. It will depend on the nature of the signal transmitted and on the kind of receiver.
Only in one case is the effect of the interfering station very simple: when the receiver passband can be assimilated to a rectangular band, and is tuned reasonably far away from the centre of the interfering spectrum. If, in addition, the interfering signal can be represented by successive uncorrelated, independent amplitudes, the interference will be assimilable to thermal noise. It will merely increase the inherent channel noise, but, for equal power, it will have the maximum effect on the loss of capacity of the channel.
- (c) If the signals transmitted can be regarded as represented by a series of uncorrelated amplitudes statistically independent of each other, it is possible to measure the spectra of the random signals and to obtain stable results, readily comparable with those obtained by measuring the spectrum of an elementary signal or of the periodic elementary signals applied to the same transmitting system, provided that the indicator of the spectrum analyser is followed by a linear, or preferably, by a quadratic integrator.
- (d) On the other hand, if the successive amplitudes of the random signal are correlated, its spectrum oscillates around the spectrum of the elementary signal and cannot show any stability, whether the same spectrum analyser is used for successive measurements or a different analyser is used. The oscillations have a complicated relationship with the bandwidth and filter characteristics of the analyser, unless the bandwidth is extremely small. In this case, the overall time of measurement may be far too long for the whole to remain coherent and reproducible. It is then preferable to replace such a signal for measurement purposes either by white noise modulating the transmitter (which is possible with a radio-telephone transmitter) or by a periodic signal (which is generally possible for radio telegraph transmitters). Laboratory measurement of radiotelegraph spectra is often effected by means of periodic elementary signals; this provides isolated points of the spectrum of the single pulse, which is the envelope of the line spectrum of the periodic pulses.
- (e) The problem of reducing interference or out-of-band radiation is reduced to the problem of finding the elementary signal which, transmitted by the same system, would produce minimum interference.

In telegraphy of the usual type, the elementary signal to be considered is identical with the unit signal of the telegraphists, the length of which is practically that of a unit interval.

In systems transmitting a continuous signal, like telephony or television, the elementary signal is the shortest isolated signal that the system can transmit; it is the output signal obtained when a very short rectangular pulse is applied to the input.

In pulse systems, the elementary signal is the basic pulse.

In systems using frequency modulation, in which the transmitters by their very nature cannot be linear, the elementary signal to be used for sampling the signal transmitted is much more difficult to define and cannot bear a simple relation to a corresponding input signal. The considerations described above and below can, therefore, be applied only with difficulty to such systems.

3. Reduction of out-of-band radiation.

If nothing is known about the characteristics of the receiver suffering from interference, or if the person transmitting is unfamiliar with the system used by the circuit experience interference, the only action which the transmitting station can take to lessen the interference is to reduce the power transmitted outside a given frequency band. We have seen, however, that, whatever signal is transmitted, the power spectrum oscillates around the spectrum of the elementary signal. The solution of the interference problem in this case lies in the reduction of the power transmitted by the elementary signal beyond a given band. But before examining methods of reducing interference which depend upon the shape of the elementary signal, some light may be thrown on this problem by a study of the consequences of Shannon's theory of channel capacity [4, 5].

It is well known that the fullest demonstration of the Hartley-Shannon theorem on the capacity of a channel in the presence of noise makes use of an expansion of the signal with the help of a staggered elementary function of the type mentioned in paragraph 2 above; but the elementary function used is Whittaker's interpolation function $(\sin \omega t)/\omega t$, which does not fulfill the condition set at the beginning of paragraph 2 for an actual elementary signal: it is not zero in any interval. Any actual signal can be arbitrarily approximated by such an expansion. For a given approximation, the expansion is found to have a uniform spectrum in a certain frequency band, beyond which it is zero. The band is wider as the signal is more closely defined, i.e. reproduced exactly at a larger number of instants.

This is paradoxical, because any signal can be represented in this way, but then it no longer produces any interference outside a certain band. This is because although the signal is correctly represented in the finite time interval when it has been actually transmitted, another arbitrary signal has been added to it outside this interval, and this completely alters the total spectrum. In actual fact, this mode of expansion assumes that the signal was known for infinite time. Under these conditions, it is obviously useless to transmit it over any telecommunication channel and the problem of interference does not arise. The Hartley-Shannon theorem, which is based on such an expansion, is thus only a limit theorem, valid only for indefinitely delayed signals. However, Kolmogorov has recently shown in which way the theory has to be changed to take into account actual signals [6].

But it is very interesting to observe that a signal, expanded in this way with the help of an infinity of elementary Whittaker functions, has statistically a Gaussian distribution under certain conditions which are more or less fulfilled for normal signals. All that is required is that the random function representing the signal should be stationary, that the characteristic function of its distribution should be regular at the origin and that the values of the function at the different sampling instants should be uncorrelated and independent ([3] Chapter XIII, page 513).

By continuity, it can be concluded from the preceding properties that a fairly long actual signal, with a roughly Gaussian statistical distribution, can give a very weak spectrum outside a certain band; this would represent minimum interference. All that would be required, would be to filter it in a suitable way and it can be deduced from the above that this filtering would be possible without inordinately affecting the signal, but that the reduction of the out-of-band radiation would be achieved only at the cost of a delay of the signal and would be greater as the delay was increased.

A well known practical example is that of the signal directly representing speech. This signal has been studied by many authors who have shown that, for a fairly long period of time and a fairly large number of different voices, its statistical distribution was approximately Gaussian, in this respect approaching white noise, which exactly satisfies the mathematical conditions posed above. The speech spectrum can thus be reduced to a very low amplitude outside a band which



is easy to determine, but it cannot be reduced to zero, as a given conversation begins at a finite moment. The reduction of out-of-band radiation can be achieved with the help of a filter without too much deterioration of articulation: the reduction is greater as the number of sections is increased, the increase of this number being the only means available of increasing the asymptotic slope of the filter. The signal delay, which increases with the number of sections, is thus all the greater as the out-of-band radiation is reduced. Some of these latter properties are well known to engineers; the very general way in which they have been obtained shows that they are independent of any hypothesis on the exact nature of the signal and the circuits used.

Unlike telephone signals, telegraph signals, which are quantized by means of adjacent signal elements, and have only two distinct levels, cannot approximate a Gaussian distribution; they are also prolific sources of out-of-band interference.

To obtain signals approximating to a Gaussian distribution with amplitude modulation, different amplitudes would have to be used at the different sampling instants; Shannon's theoretical signal considers amplitudes whose difference at two distinct instants is at least equal to the noise level. The convergence theorems of the sum of random variables towards a Gaussian variable [1] shows how a Gaussian signal can be obtained in this way: the overall signal must be constituted by the sum of a large number of signal elements, all small and occurring at random instants.

If only a limited number of signal elements can be superimposed, occurring at random instants and statistically independent, and if the overall signal is to have a Gaussian distribution, it can be seen, by application of Cramer's theorem, that a signal element represented by the inverse function of the Gaussian distribution function should be employed. Such a signal could not be exactly achieved. The preceding signal, with a large number of combinations, seems to be achievable.

4. Reduction of bandwidth.

This theoretical problem differs at least on the surface from the one above, although it may lead to the solution of the same physical problem. It has been shown above that the problem can be reduced to finding the best elementary signal, without, at least as a first approximation, there being any need to take account of the information transmitted, provided, of course, that the elementary signal permits transmission of such information.

If an attempt is made to find an elementary signal providing maximum power within a given frequency band, as suggested by the definition of occupied bandwidth, the result will obviously be the sinusoidal signal and the Whittaker signal referred to above. These two signals are physically unobtainable and do not meet the conditions stated above for the elementary signal: they have existed for infinite time. Their spectrum is zero outside a certain band whereas we must use signals which are zero before an instant when they begin, subsequently to be prolonged indefinitely and vanish progressively, in accordance with an exponential law. The spectra of these latter signals cannot be zero outside any given band.

Not all elementary signals which satisfy these simple conditions can be acceptable; in telegraphy, in particular, and in most other cases, we wish to use an elementary signal with a build-up time lower than a given value or a limited practical duration. Such a condition, even if physically accurate for a category of signals of a certain given shape, cannot easily be formulated for a signal whose shape has still to be determined. A similar difficulty is encountered in designating mathematically the concept of "bandwidth".

To facilitate formulation of the problem, other concepts which may be equivalent to "build-up time" of "significant duration" or "bandwidth" must be used. Gabor, taking up a theory established by Pauli and Weyl, seems to be the only author to have dealt with the problem in a general sense [7]; he has given a definition of "effective duration" and "effective spectral width". These effective values are the r.m.s. values of the signal and of its spectrum, centred respectively round a mean time and a mean frequency.

Gabor then shows the existence of a relation between these two quantities, similar to an uncertainty relation, according to which their product cannot be less than unity. Since, in addition, our aim is to find an elementary signal with a minimum duration and as narrow a spectrum

as possible, the required conditions must be fulfilled, in the Gabor sense, by signals which make the uncertainty product near to unity. It has recently been shown that this relation is only exact when the spectrum function is zero for frequency zero [8]. This is not usually so, but in the radio case under consideration where the r.m.s. spectrum width is negligible with respect to the carrier frequency, the spectrum energy is almost zero for frequency zero and the Gabor relation is fully applicable. The corrective term should not be considered unless the same theory is to be applied, for example, to carrier frequency telegraph systems, which this report makes no attempt to deal with.

The limit value of the uncertainty product is attained only in the case of a signal whose shape is represented by a Gaussian function and whose spectrum is a function of the same form. This signal has the same drawback as the Whittaker signal: it begins in the infinite past and cannot, therefore, in practice be realised with accuracy. Nevertheless, on both sides, its decrease towards zero is extremely rapid, contrary to that of the Whittaker signal, which is slow. It should, therefore, be easy enough to approach the theoretical optimum shape by curtailing the signal on one side and neglecting the remainder of one of the infinite branches.

Several investigators have shown that such approximations to a Gaussian signal can be obtained with any degree of accuracy required, by means of fairly simple physical circuits. Vasseur [9] uses simple resistance-capacity sections separated by vacuum tubes; he proves that if the input signal in such a system is a very short pulse, the output signal approaches the Gaussian signal when the number of sections increases indefinitely. Naturally, the main part of the signal recedes, at the same time, indefinitely along the time axis: a signal delay proportional to the square root of the number of sections must therefore be admitted. But, since a great many resistance-capacity sections and nearly as many vacuum tubes have to be used, the system is hardly a practical proposition. Indjoudjian [10] has shown that the same result can be obtained with an inductance-capacity low-pass filter having a non-constant characteristic impedance, and the same number of sections as above. Since the dissipation of the network is low and fewer amplifying tubes are required, the latter filter would appear to be more economical.

Practical use of the Gaussian signal had already been advocated before Gabor, particularly in the United States, for television [11]. In the United Kingdom, Roberts and Simonds [12] had already described its properties as long ago as 1943 and 1944. Chalk [13], in seeking to establish the best signal shape on the lines above, while bringing into play the characteristics of a circuit under the influence of interference, arrived *inter alia* at the Gaussian signal. But if radio channels subject to interference are taken as a whole, circuits of unknown characteristics are no longer to be considered, and the overall measurement of the interference is determined by the out-of-band energy; therefore, in the Gabor sense, at least, the Gaussian pulse provides the best shape.

Marique [14], after examining, in a similar way, the case of signals with Gaussian flanks, came to the conclusion that they offered no marked advantages over other shapes, and in particular over sine squared signals. However, these signals are not, strictly speaking, Gaussian signals; the considerations above have shown that in telegraphy each telegraph instant should be transmitted by a Gaussian signal with joined elements represented by successive elementary signals of such a length as to ensure that the resulting undulation on the signal along the maximum is small. In a more recent contribution [15], the same author, comparing several shapes of signal, shows that the higher the degree of the first term of its power series expansion, the weaker the interference caused by the signal. This property is very general: a reduction in out-of-band radiation required a rapid decrease in the spectrum with movement away from its centre: the order of asymptotic decrease of the spectrum is equal to the order of the tangent at the origin of the signal beginning at the origin of time [16]. The signal delay, on the other hand, increases with the degree of the first term of its power series expansion. Thus, the quite basic principle in the theories of Shannon and Gabor is once again confirmed, whereby the interference can be reduced only if the signal is delayed, the best results being obtained when the delay is infinite (that is, of course, when there is no telecommunication whatsoever).

Numerical calculations made with the practical signal shapes obtained by the Vasseur process seem to indicate that a shape, sufficiently close to the Gaussian shape, can be obtained for the principal part of the signal with a small number of filter sections, but a sufficiently low value of the product of build-up time and bandwidth occupied is only reached when the number of sections is much greater, i.e. only when the signal has suffered a marked delay.

Chalk [13], M. S. Gourevitch [17] and J. A. Ville [19] have determined the form that a pulse of finite duration should have so that a given frequency band contains the maximum energy.



Gourevitch has also determined the bandwidth containing 99% of the total energy for various forms of pulses. It has been shown also that the cosine squared shaped pulse, although occupying a wider band than the trapezoidal pulse, had the advantage of a faster decrease of its power spectrum components outside the occupied bandwidth, and therefore would produce smaller interference for sufficiently wide channel spacing [18]. But these authors have not considered the concept of the delay of the signal. A sufficiently delayed Gaussian shaped impulse would give a much faster decrease of the power spectrum components than any of their optimum signals of finite duration.

When determining the form of a telegraph signal element by such methods, one must consider that such a signal element should have a sufficiently long flat portion; if the optimum pulse is found to be not satisfactory in this respect, a suitable signal element can be constructed with several time staggered pulses.

The problem should therefore be considered in its practical aspects as being essentially a function of signal delay, more than of signal shape. A delay in telegraphy is not a very serious matter: one equivalent to the length of a letter seems to produce satisfactory results; and there seems to be no need to exceed a delay longer than that corresponding to a word. These delays are of the order of those obtained with the mechanical devices in certain existing multiplex systems.

Another reason for the necessary delay is found if one considers the adaptation of the signal itself to its transmission in the minimum bandwidth. In particular, in this respect, if "optimum coding" is sought, it can be shown that the signal must be delayed. The same applies if the signal is to be transmitted after frequency compression and to be expanded when received. The importance of delay has been stressed in the latest version of a C.C.I.R. question on information theory [20].

In conclusion, it is well to cite some of Gabor's further researches on other forms of signals, as they may give rise to complementary studies. Considering that an exact Gaussian signal is unattainable, Gabor shows that the signal which is zero outside a certain time interval and which has the smallest "effective bandwidth" is represented by half a sine-wave; reciprocally, the signal with the shortest "effective duration" has a half-sine-wave spectrum. For these two reciprocal forms, the uncertainty product is only 1.14, which is only a little higher than the theoretical optimum. Gabor remarks that "sine-squared" signals, also called "raised cosine" signals, give substantially similar results. Use of this sine-squared shape is justified in television by power considerations, and it is closer to the Gaussian optimum. Wheeler and Loughren [11] were the first to propose the use of clipped sine-wave signals for television, but their justification was empirical.

All of these latter signals, however, are still not physical, because their attenuation is not exponential and they finish abruptly. It remains to be determined which is the best signal which will become zero before a given instant, will decrease exponentially, and will have a fixed maximum delay. This problem would not appear easy to resolve within the framework of Gabor's theory, nor is it certain that the research will lead to a result different from the approximation to the Gaussian signal given by Vasseur and other authors, which so far seems to be the most satisfactory process, both from the theoretical and from the practical points of view.

5. Reduction of interference, from the standpoint of the transmitter and the receiver taken as a whole.

Filtering at the transmission end to reduce interference is limited by the attendant distortion of the signal. The quality of the signal itself is fully defined by the form of the elementary signal, i.e. the shortest signal that can be emitted by the quadripole representing the transmitter. But it is at the output of the receiver that the desired quality of the signal must be maintained. Hence, in interference problems, we have to consider not only the characteristics of the receiver suffering interference, but also those of the correspondent's receiver, which in many cases can be represented, like the transmitter, by linear quadripole (the most important exceptions are the cases in which frequency modulation is used).

Even when we limit ourselves to energy consideration, that is to say, when we do not take into account the kind of system used nor the nature of the signal, the problem of interference with one transmitter and two different receivers is a complicated one. There would seem to be no simple general solution.

The problem is easier if we assume two identical receivers. We can then assume that since two identical receivers are in principle designed to receive two signals of the same kind, the transmitters are also identical. We shall then be able to inquire under what conditions the mutual interference between two such circuits of the same nature is minimum, when they operate on neighbouring frequencies. If we make some extra assumptions—we shall not go into them here, since they do not appear to affect the general validity of the result obtained—Villepelet [21] has shown that in these circumstances the mutual interference is minimum when the equivalent quadripoles representing each transmitter and each receiver are identical. This result fully determines the quadripoles, for we can also look for the optimum form of the filter to be used (as mentioned above), together with the minimum bandwidth and the maximum delay which will retain the desired signal quality. The quadripole thus defined represents the unit transmitter-receiver. If iterative, it will suffice to cut it in two, allocating an equal number of sections to the transmitter and to the receiver, to obtain Villepelet's optimum. With present-day equipment, at least in radiotelegraphy and broadcasting*, this optimum is very far from being attained. Receivers are in general equipped with relatively narrow filters, with rather steep slopes, while transmitters are filtered little or not at all. The rest of Villepelet's paper shows the drawbacks of this inadequate filtering in every case.

Of course, this equality between the transmitter and receiver quadripoles (other things being equal) allows minimum spacing between neighbouring channels. Hence, if a frequency band is fully assigned to circuits of the same kind juxtaposed in frequency, this condition will allow the maximum number of circuits to be accommodated. For certain kinds of service and certain bands, where this juxtaposition of circuits of similar nature is more or less imposed by circumstance, the above conclusion is fully applicable.

In some other bands (for example, the HF bands allocated to the fixed services) such a juxtaposition is in no sense compulsory, since the circuits are generally operated with a few substantially different classes of emission. If, in such a band, the use of a particular class of emission and system definitely predominates over all the others, then, clearly, the condition of equality of the transmitter and receiver quadripoles must be applied to the corresponding apparatus, since a particular circuit is more likely to cause reciprocal interference with a circuit of the same kind than with a circuit of a different kind, even if frequencies be assigned at random.

We shall now have to consider circuits of different kinds to be placed, in more or less equal numbers, in the same frequency band. Is there any advantage in assembling circuits of the same kind in the same section of the band, or should they be interlaced so that a circuit is, if possible, flanked by circuits of different kinds? As thus stated, there is no one general answer to this question; it depends on very many parameters, and is difficult to put precisely. Existing theories [4, 5] can only suggest partial replies, by assimilating the interfering station to Shannon's noise generator, and by taking the channel capacity into consideration, as well as the quantity of information actually transmitted. Blachman [22] has recently shown how the problem can be imagined as a game between two players, one of whom wants to transmit information at the highest possible speed by choosing the best system, while the source of interference tries to limit this speed by choosing the most damaging interference**. The complexity of this problem arises from the fact that the two are not independent. But, for a given mean energy in a given limited band, the interference which most reduces the channel capacity is Gaussian white noise, and we have already described how this can be produced by an interfering transmitter. A circuit subject to such noise will suffer little if the channel capacity is adequate, and if the transmission speed is limited to suit this capacity as reduced by interference. Again to make the best of things, it should also use a signal assimilable to Gaussian white noise, that is to say, a signal with a limited, uniform spectrum and with uncorrelated, independent amplitudes. Among the most usual classes of emission, those which produce such interference are amplitude-modulation radiotelephone trans-

* In general, with sound broadcasting, the bandwidths of amplitude-modulation transmitters are at least double those of the corresponding receivers.

** As thus stated, Blachman's problem corresponds well to intentional interference, but the same reasoning can be applied to cases when assignments are requested at random as and when channels become vacant, without making allowance for the kind of circuits juxtaposed.

mission (DSB, SSB or ISB). Hence, in assigning frequencies, these emissions should be placed close to the circuits which are the least sensitive to the interference they cause. These will be emissions belonging to the same class. Thus to the cases in which emissions of the same class are *naturally* juxtaposed in the same band, we have added at least one case in which they *should be* juxtaposed in the interests of the circuits as a whole and to save band space. This having been done, we can then readily apply Villepelet's principle to reduce the energy of the interference, if that has not been done already.

We must not generalize and assume that this is only one instance of a general principle, according to which circuits of the same kind should always work on adjacent channels. In the present state of theory, there is no justification for such principle. Indeed, there are several reasons why it may be, in part at least, false. If, for example, we consider a synchronous telegraph circuit, it would seem that an excellent source of interference would be an emission of the same type, of the same speed, and with its characteristic instants synchronized, the messages being, of course, independent (telegraph apparatus can respond to false signals only when they are more or less synchronized with their distributors). Here white noise is not necessarily the best source of interference, because the spectrum of the signal cannot be assimilated to a limited, uniform spectrum.

In view of the complexity of the problem it would seem preferable to determine experimentally the possibilities of juxtaposition of circuits of various types. Especially in the fixed services, we are dealing with relatively few systems, with fairly stable, well-known characteristics for which no theoretical model affording a possibility of accurate reasoning could, except with very great difficulty, be devised. But it is relatively easy to carry out laboratory measurements of mutual interference under stable conditions, by eliminating the effect of variable propagation conditions.

6. Reduction of the effect of interference by adapting receivers to the interference.

In practice, all existing receivers are designed to receive and decode the desired signal as well as possible. Protection is only envisaged against white noise, never against interference of other kinds, which may be very different, except, for instance, with multiplex in which the adjacent channel belongs to the same system. Now, since interference is inevitable, it would conceivably be of advantage, in some cases at least, to determine the receiver characteristics to suit both the signal to be received and the interference. This will be feasible only if the interference is of a particular kind, or at least has characteristics of a certain kind. It is inconceivable that the receiver should reject an interfering signal by making a distinction between it and the signal desired, if it does not in some sense "know" some of the characteristics of the interference. Protection will be the more effective the better the receiver "knows" these characteristics. To realize this, it will suffice to consider an obvious extreme case, namely, when the interfering signal is sinusoidal, in the band of a signal such as a radiotelephone signal. If we know accurately the frequency (stable) of the interference, the only parameter on which it depends, we shall be able to filter it by a very narrow filter neutralizing a very small receiver frequency band without in practice, affecting, as we know, the reception of the signal desired.

To deal with the problem of the adaptation of the receiver, P. Deman [23], like Gabor, has proposed that the signal be represented by a series of functions staggered both as regards frequency and time. Each function represents a single elementary signal, like those considered in § 2 and 3 above, and the various elementary signals are staggered in time. But, in addition, they modulate sinusoidal carriers of different frequencies (and no longer a single carrier, as heretofore). Hence every elementary signal depends on two discrete parameters, the switching instant and the frequency, and on one continuous parameter, the amplitude. One or more of these can serve for recognition of the signal by the receiver, while the remainder represent the information. Thus, for example, interfering signals can be distinguished from the desired signals by the frequency parameter. The filtering and decoding functions of the receiver can be represented by linear transformations, the kernels of which are identical with the staggered elementary functions which represent the desired signal. The effect of the interfering signals then takes the form of interaction between two functions, one desired, the other undesired. Cancellation, or rather reduction of the interference effect (since full cancellation is impossible with linear physical circuits) can be investigated by using the theory of orthogonal functions.

Such a procedure might be convenient for a study of interference problems, from an angle which seems to have escaped attention so far.

BIBLIOGRAPHY

1. LEVY, P. *Théorie de l'addition des variables aléatoires*, Gauthier-Villars (Paris).
2. MARIQUE, J. Réponse des analyseurs de spectres radioélectriques à des signaux Morse non périodiques. *Annales des Télécommunications*, (July-August 1954 and September 1954).
3. BLANC-LAPIERRE and FORTET. *Théorie des fonctions aléatoires*, Masson (Paris).
4. SHANNON, C. E., and WEAVER, W. *A mathematical theory of communication*, University of Illinois Press, (1949).
5. SHANNON, C. E. Communication in the presence of noise. *Proc. I.R.E.*, 37, 10, (1949).
6. KOLMOGOROV, A. N. *Theory of communications*. Editions of the Academy of Sciences, Moscow, (1956). *Arbeiten zur Informations-theorie*, I. VEB, Deutscher Verlag der Wissenschaften, Berlin, (1957).
7. GABOR, D. Theory of communications. *J.I.E.E.*, Part III, Vol. 93, November, 429-457, (1946).
8. KAY, I. and SILVERMAN, R. A. On the uncertainty relation for real signals. *Information and Control*, Vol. 1, 1, 64-75, (September, 1957).
9. VASSEUR. Impulsions de Gauss. *Annales de Radioélectricité*, (October, 1953).
10. INDJOU DJIAN. Réseau de mise en forme d'impulsions électriques, French Patent No. 660.505, (22nd December 1953). Réseau électrique de retard, Patent of same date.
11. WHEELER and LOUGHREN. *Proc. I.R.E.*, (May, 1938).
12. ROBERTS and SIMMONDS. *Philosophical Magazine*, 822-827, (1943) and 459-470, (1944).
13. CHALK. The optimum pulse-shape for pulse communications. *Proc. I.E.E.*, Part III, Vol. 97, 46, (March, 1950).
14. MARIQUE, J., Forme des signaux radiotélégraphiques et interférence entre voies adjacentes. *Annales des télécommunications*, (February, 1956).
15. Doc. No. 9 (Belgium) of Warsaw, 1956.
16. VAN DER POL, B. and BREMMER, H. *Operational calculus*. Chapter VII, Cambridge University Press.
17. GOUREVITCH, M. S. Signals of finite duration with a maximum energy in a particular band. *Review of the U.S.S.R. Academy of Sciences, Radio and Electronics*, Vol. I, 3, (1956). The frequency band occupied by a pulse transmission. Same Review, Vol. II, 1, (1957).
18. Doc. No. 120 (U.S.S.R.) of Los Angeles, 1959.
19. VILLE, J. A., and BOUZITAT, J., Note sur un signal de durée finie et d'énergie filtrée maximum. *Câbles et Transmissions*, Vol. 11, 2, (April, 1957).
20. Question No. 133 (III): Communication theory, Warsaw, 1956.
21. VILLEPELET, J. Etudes théoriques et expérimentales du brouillage mutuel entre systèmes de radio-communications. *Annales des télécommunications*, Vol. 10, 12, (December, 1955) and Vol. 11, 1, (January, 1956) (Summarised for the C.C.I.R. in Doc. No. 174 of Warsaw, 1956).
22. BLACHMAN, N. M. Communication as a game. *I.R.E. Wescon Convention Record*, 61, (1957).
23. DEMAN, P. Spectre instantané et analyse du signal simultanément en fréquence et en temps. *U.R.S.I.*, Boulder, Colo., (1957).

REPORT No. 97 *

BANDWIDTH OF TELEGRAPHIC EMISSIONS A1 AND F1. EVALUATION
OF INTERFERENCE PRODUCED BY THESE EMISSIONS

(Study Programme No. 126 (I))

(Los Angeles, 1959)

1. Introduction.

A reduction of interference caused by telegraphic transmissions may be obtained by adequately shaping the transition between mark and space in an A1 or F1 signal thereby reducing the bandwidth occupied for a given keying speed.

Two documents leading to practical solutions, that can be used to modify the existing systems, have been submitted to the C.C.I.R.

The study of the bandwidth occupied by a given telegraphic system, in identical keying conditions, shows that it is worth while to increase build-up time to the maximum value compatible with the proper working of the receiving equipment.

2. Spectrum distribution and bandwidth occupied by F1 emissions.

The first document (No. I/23 (Japan) of Geneva, 1958), describes the spectrum distribution of F1 emission in detail, and deals with the occupied bandwidth.

2.1 The spectrum distribution of F1 periodic emissions can be expressed by the following empirical formula relating to the overall characteristics (neglecting fine variations):

$$A(x) = E \cdot \frac{2}{\pi} \cdot \frac{1}{m} \cdot \left\{ x^u (x^2 - 1) \right\}^{-1} \quad (\text{for } x > 1) \quad (1)$$

where

- $A(x)$ = amplitude of the spectrum at x ,
- x = frequency deviation from the centre frequency/half the frequency shift,
- E = amplitude of unmodulated carrier,
- m = modulation index,
- D = half the frequency shift (c/s),
- τ = build-up time of signal (seconds),
- $u = \sqrt{5 D \tau}$.

This formula (1) shows that the overall envelopes of the spectra of periodic F1 emissions are similar insofar as the value of $D\tau$ is constant; in this case $A(x)$ varies as $1/m$.

The effect of the build-up time decay form of the keying signal on the microscopic shape of the spectrum has been studied. The study has shown that this effect was small for values of $D\tau$ less than 0.15 or between 1 and 5. When the mark and space duration are not equal, the form of envelope varies widely with the product of $D\tau$ by the shortest signal duration, but it is always similar to that produced by reversal signals (dots) with the same build-up time.

Fig. 1 gives a comparison between the results of measurements made on spectra and the corresponding values calculated with formula (1) above. The agreement is fairly good for the values of x larger than 1.2, when the value of the product $D\tau$ is not too small. Fig. 2 shows a more extensive set of curves calculated from the same formula (1).

* This Report was adopted by correspondence without reservation (see page 9).



2.2 When the signal is aperiodic, as it is in actual traffic, it seems to be reasonable to express the spectra in the form of a power distribution. The average power density per c/s of an F1 emission can be expressed by the following formula

$$\text{Average power density} = \frac{W_0}{2D} \cdot \frac{1}{m^2} \cdot \frac{4}{\pi^2} \left\{ x^u (x^2 - 1) \right\}^{-2} \quad (2)$$

where W_0 = total power

and D , m , x and u are as before.

Integrating the above formula (2), between suitable limits, we obtain the total power W' of the components which lie outside the specified frequency band. Fig. 3 represents values of the bandwidth calculated in terms of m and $2D\tau$, for $W'/W_0 = 0.01$ and $W'/W_0 = 0.001$.

Two important conclusions with respect to the spectrum distribution of F1 emission in actual traffic may be obtained. Firstly, the form of the overall envelope is determined only by the product of build-up time and frequency shift, while the duration of the flat part has negligible effect on it. Secondly, the value of the level is determined approximately by the number of signal-build-ups per unit time.

2.3 The occupied bandwidth, L , of F1 emission can be expressed by the following empirical formula in c/s:

$$L = D \left[2 + \left\{ (3 - 4 \sqrt{\alpha}) \cdot m^{-0.6} \right\} \right] \quad (3)$$

where α = build-up time/signal duration.

This bandwidth has only slight dependence on the form of the build-up of the signal, whereas the out-of-band spectrum distribution depends very largely on this form.

The following table shows the maximum divergence between the results obtained using this empirical formula and those obtained by exact calculations as summarised in Document 236 (France) of Geneva, 1951:

3 %	for $\alpha = 0$	; $2 \leq m \leq 20$
9 %	for $\alpha = 0.08$	; $1.4 \leq m \leq 20$
10 %	for $\alpha = 0.24$	; $2 \leq m \leq 20$

The divergence is always less for the higher values of m . This comparison shows the limits within which formula (3) can be used with reasonable accuracy.

Finally, Figure 4 shows a fairly good agreement between formula (3) and the results of measurements made on periodic or random signals with bandwidth measuring equipment of the type described in Recommendation No. 229, §1.2.

3. Spectra and filtering of A1 and F1 emissions. Interference produced in adjacent channels.

The second document (No. I/31 (U.S.A.) of Geneva, 1958) gives a detailed description of the spectral distribution of A1 and F1 emissions.

The results given are similar to those described in Document I/23 of Geneva, 1958 and also provide practical means for increasing the signal build-up time by the use of keying filters.

The choice of usable filters for both classes of emission, and factors intervening in that choice, are discussed.

3.1 Spectra and filtering of A1 emissions.

The high-frequency spectrum is the product of the spectrum of square signals, formed at a given keying rate, by the low-pass filter transfer admittance centred on the carrier frequency.

Non-linearity after the low-pass filter leads to the reintroduction of considerable power into adjacent channels.

The transient response of the filter is primarily determined by the form of its transfer characteristic in the pass band out to approximately 20 db attenuation. Large overshoot should be avoided, primarily to make full use of the transmitter power. Details regarding the structure of suitable filters are given in references 3, 4 and 8 of Document I/31 of Geneva, 1958.

The minimum necessary value of T defined as the ratio between the 6 db filter pass band and the fundamental keying frequency (equal to half the telegraph speed in bauds) is largely determined by the synchronization requirements of the terminal telegraphic equipment and also by the frequency stability of the transmitter and the receiver. These values vary from 2 for very good synchronization and frequency stability, to 15 when the frequency drift is appreciable and teletypes are used. Propagation conditions should also be considered. The larger values are required by the fact that proper operation of the teletype equipment demands a sufficiently long flat portion of the signal element.

The signal shape to be considered is the shape at the output of the radio receiver; so the shaping undergone by the signal in the receiver filters should be taken into account, noting that these filters should be at least as narrow as the transmitter filters.

The following table shows, as a function of T , the percentage of time during which the signal element is flat within 1%, for a minimum over-shoot filter:

$\frac{\text{Length of flat portion}}{\text{Length of signal element}}$	0 % (sinusoidal signal)	50 %	90 %	100 % (rectangular signal)
$T = \frac{\text{6 db low pass bandwidth}}{\text{Fundamental keying frequency}}$	1.6	3.2	16	∞

Since the factor, T , is predetermined, a good way of reducing the spectrum beyond the 20 db attenuation point is to use multi-sectioned filters.

3.2 Spectra and filtering of F1 emission.

An approximation of the high-frequency spectrum valid for frequency deviation from the centre frequency greater than the frequency shift and for values of T greater than 3, can be obtained by obtaining the product of the spectrum of square signals having a given keying rate and the low-pass filter admittance centred on the nearest space or mark frequency.

Minimum overshoot is not essential unless the transmitter is required to operate on more than two frequencies (for instance, as in four frequency diplex); more accuracy in the determination of each level is then possible. Also, the transition curve pattern remains the same for different keying rates.

3.3 Adjacent channel interference.

Interference to adjacent channels depends on a number of parameters and its rigorous calculation is extremely difficult. Since it is not necessary to calculate the value of this interference with great precision, semi-empirical formulas and graphs can be used.

Interfering keyed emissions produce at the receiver output:

- a transient response, the amplitude of which is proportional to the bandwidth of the receiver and inversely proportional to the telegraph speed. For a given receiver bandwidth, this response may be reduced only by filtering of the emission at the transmitter;
- a quasi steady state response caused by the carrier of the interfering emission. For a particular frequency difference between the adjacent channels and for a particular receiver bandwidth, this response may be reduced only by increasing the slope of the selectivity curve of the receiver.

For most of the usual radio communication systems, the ratio of the carrier amplitudes of the desired signal and of the undesired signal which can be tolerated at the input of the interfered receiver may be calculated as a function of the following parameters:

- R = minimum ratio of desired to undesired carrier amplitudes at the receiver input, necessary for satisfactory reception;
- r = minimum amplitude ratio of the desired signal response to the maximum response to the undesired signal at the output of the intermediate frequency amplifier, necessary for satisfactory reception.



Values of r , characteristic of the usual classes of emission are given in the following table:

Class of emission for the desired signal	Quality of reception (r)	
	Interference not objectionable	Desired signal fairly readable
Radioteleprinter F1	2	1.5
Commercial radiotelephone	2 to 10	0.1 to 1
High quality radiotelephone (or music) . .	100	2 to 10
Facsimile A4	30	4
Facsimile F4	6	2

The exact value of r to be employed depends to some extent upon the keying speed, receiver bandwidth and other characteristics of the system.

$A(f)$: Spectrum of rectangular signals as shown in Fig. 5.

Δf : Half the frequency shift ($\Delta f = D$ from Recommendation No. 145) (Take $\Delta f = 0$ for amplitude modulation).

f_r : Fundamental keying frequency, or one half the telegraph speed in bauds.

$m = \frac{\Delta f}{f_r}$: modulation index.

f_c : Cut off frequency at 6 db point of low pass filter.

f : Frequency difference between the desired and undesired carriers (centred carriers).

$Y(f)$: Transfer admittance of the transmitter low pass filter. Where the interfering signal is amplitude modulated $Y(f)$ is centred on the carrier where $f = 0$. Where the interfering signal is frequency modulated, one uses $B(f - \Delta f)$. This admittance is centred on the nearest working or resting frequencies where $f = \Delta f$. The values of $Y(f)$ are shown in Fig. 6.

$Y_R(f)$: Transfer admittance of the receiver centred in the same way as described for $Y(f)$. The values of $Y_R(f)$ are shown in Fig. 7.

F : 6 db bandwidth of intermediate frequency of receiver.

The semi-empirical formula using the above factor is as follows:

$$R = r \left[\frac{F \cdot A(f) \cdot Y(f - \Delta f)}{2f_r} + Y_R(f - \Delta f) \right]$$

The first term of this formula gives the transient response of the receiver and the second one the quasi steady state response.

Fig. 8 shows some results obtained with this formula.

The foregoing does not take into account certain non-linear effects which may occur in the receiver in the presence of strong interference. It is essential that the receiver employed have a sufficiently large linear dynamic range prior to the circuits providing the selectivity, for the preceding formula and graphical data to be applicable.

4. Measurements on spectra of F1 signals.

A third document (Doc. I/14 (United Kingdom) of Geneva, 1958) contains the results of measurements of the spectrum of F1 signals having various build-up waveforms. These results indicate that the signal with linear build-up (trapezoidal keying) appears to have a narrower spectrum than those of other waveforms tested.

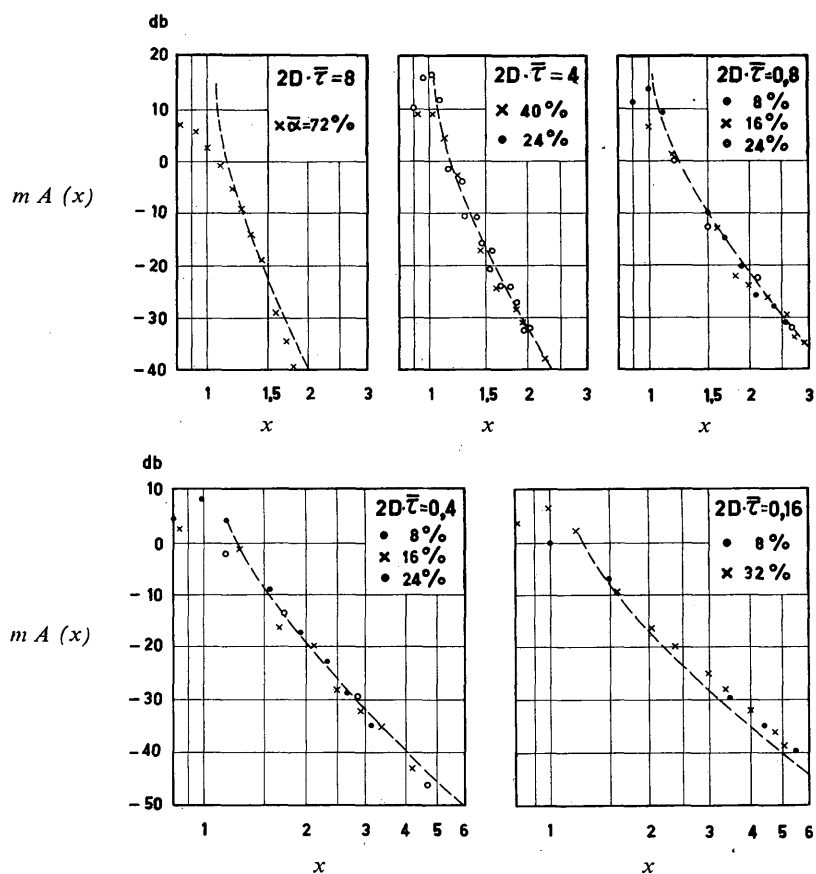


FIGURE 1
Spectra of FI emissions
— — — — — Calculated from empirical formula (1).

$\bullet \circ \times$ Measured points.

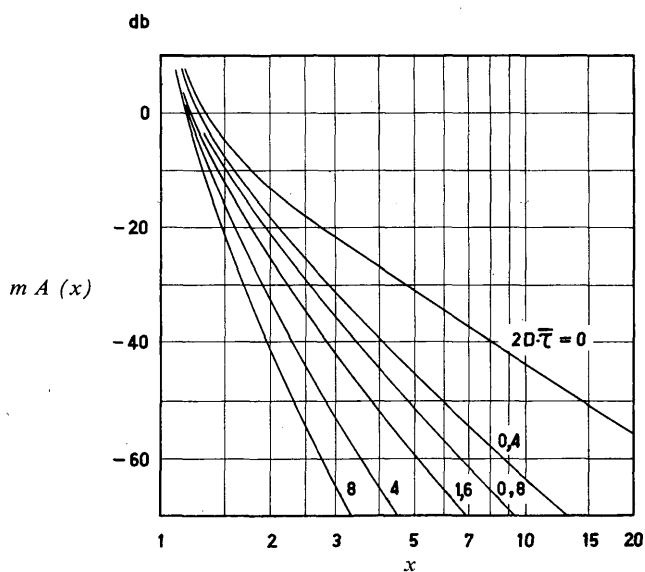


FIGURE 2
Spectrum distribution of FI emission
calculated from empirical
formula (1)

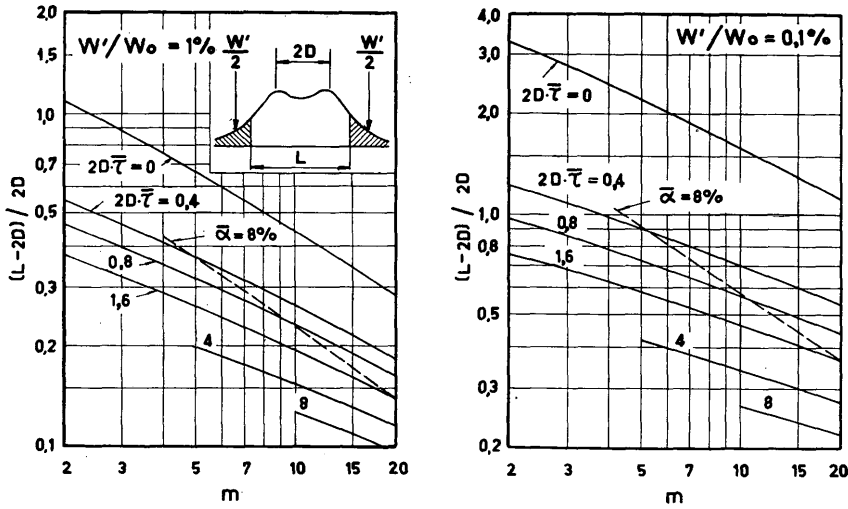


FIGURE 3
Bandwidth calculated from Formula (2)

W_0 = total power.

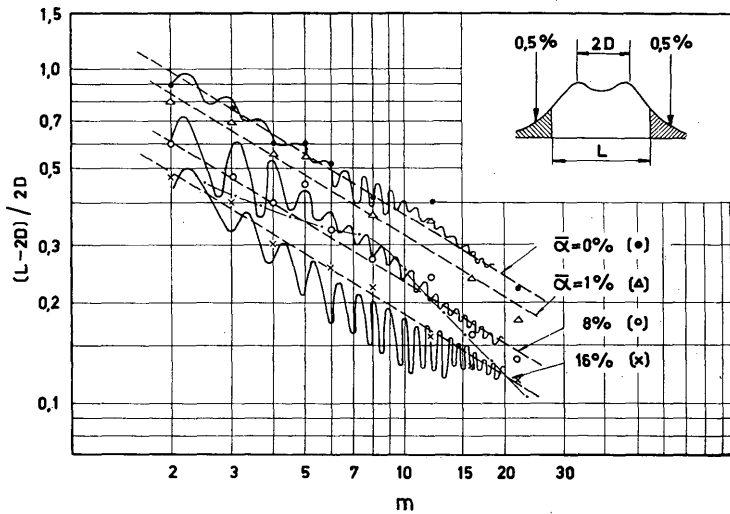


FIGURE 4

Comparison of occupied bandwidth obtained from Spectrum Analyser,
bandwidth measuring device and the C.C.I.R. formula

- · — · — Calculated from the formula given in Recommendation No. 230.
- — — Calculated from Formula (3).
- Calculated from spectra obtained from Spectrum Analyser.
- Δ ◦ x Measured points obtained with the bandwidth measuring device.
- τ Build-up time/signal duration.

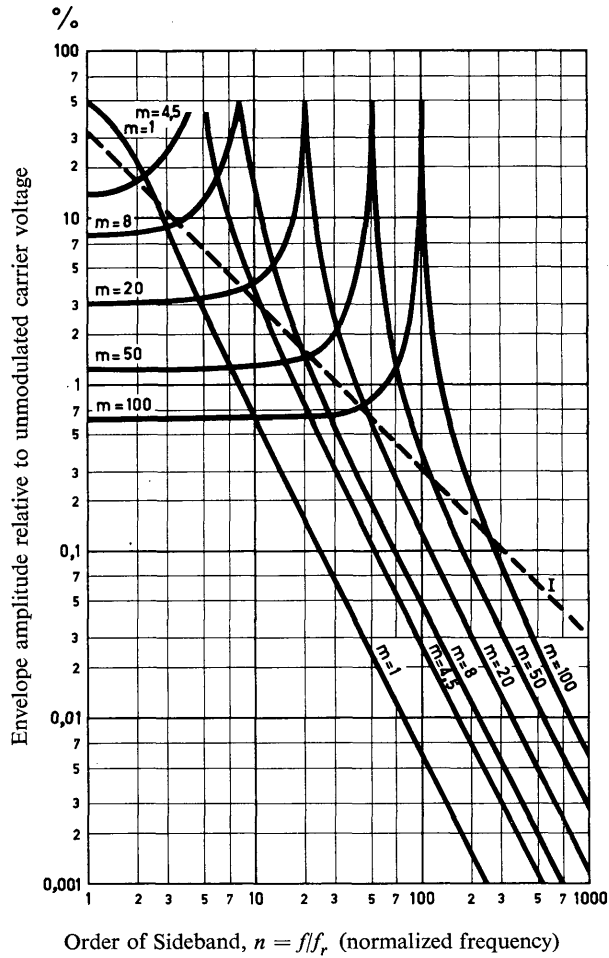


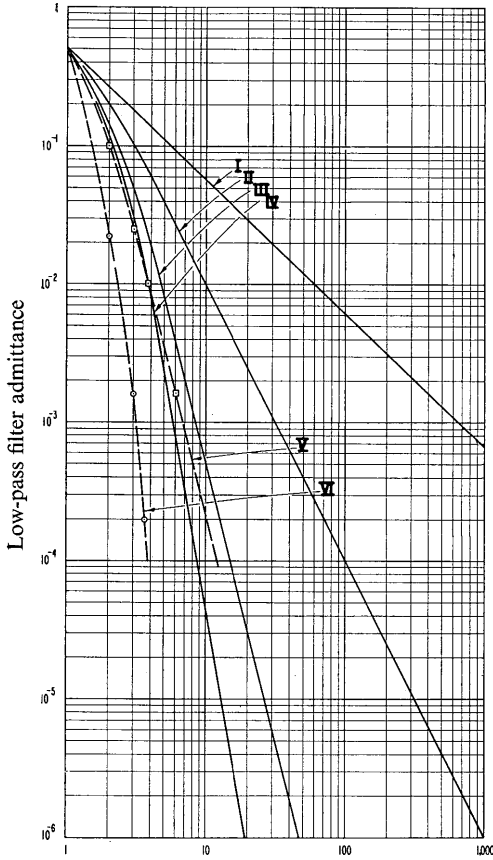
FIGURE 5

Envelopes of square-wave frequency-shift keying spectra

Curve I: A1 square-wave.

Asymptotic formula good in linear region of curves:

$$A_n = \frac{2m}{\pi \cdot n^2} ; n = \frac{\Delta f}{f_r} \text{ (modulation index).}$$



Normalized frequency
 $(f - \Delta f) / f_c = (f - \Delta f) / T \cdot f_r$

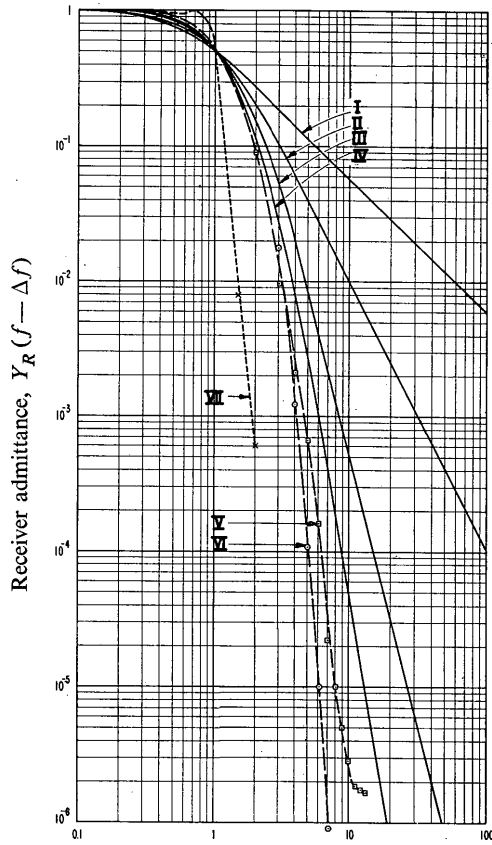
FIGURE 6

Low-pass filter admittance curves, normalized to the 6 db cut-off frequency ($f_c = T \cdot f_r$)

- Calculated curves :
- I Isolated, identical RC filters.
 - II 1 section.
 - III 2 sections.
 - IV 4 sections.
 - V 6 sections.

Measured curves :

- V 4 section RC filter with feedback for optimum response.
- VI 4 section LC filter with optimum transient response.



Frequency separation relative to f_c
 $(f - \Delta f) / f_c$

FIGURE 7

Receiver admittance curves, normalized to the 6 db cut-off frequency ($f_c = \frac{1}{2} F$) for obtaining quasi steady-state response

Calculated curves :

- I, 1 stage; II, 2 stages; III, 4 stages; IV, 6 stages.

Measured curves :

- V Good receiver with 4 tuned stages, i.e. two sets of coupled circuits, measured at high frequency so that RF stages are not effective.
- VI Good receiver as above, but measured at low frequency so that RF stages are effective.
- VII Seven- section electro-mechanical filter.

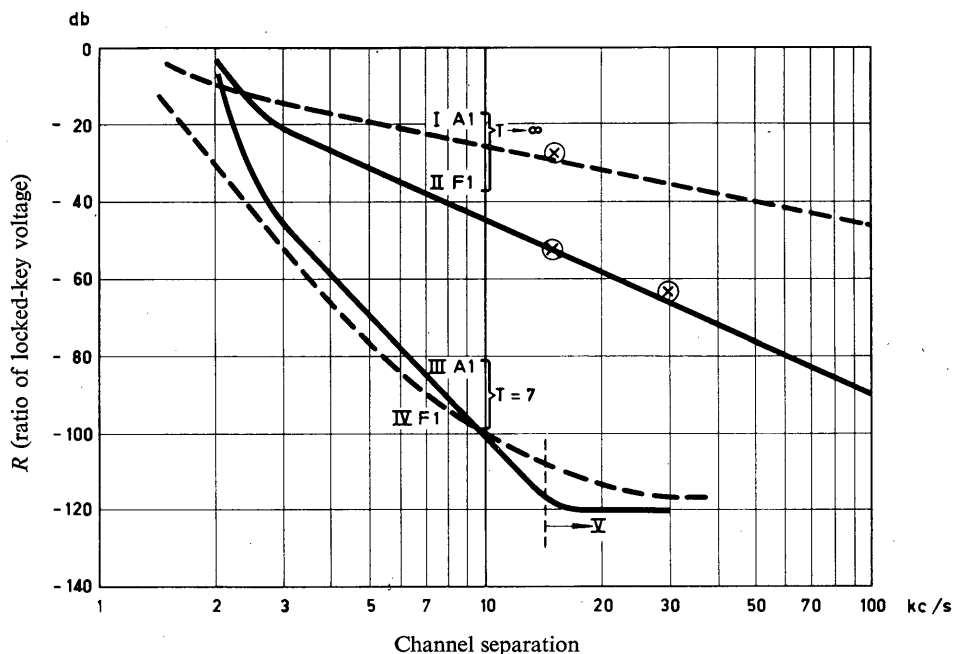


FIGURE 8

Values of R for the transmitter and receiver characteristics indicated

Receiver: 2 sets of double-tuned coupled circuits in the IF section with a 6 db bandwidth of 1.5 kc/s (average voltage bandwidth 1.6 kc/s) with an assumed IF output ratio r of 2 (see § 3.3).

Transmitter: Keying rate 46 bauds; $f_r = 23$ c/s with filtering factor, T , as shown. For F1, $\Delta f = 415$ c/s ($m = 18$).

Curves I and II: No keying filter, $T = \infty$.

Note: Any improvement in receiver out-of-channel rejection will not reduce R for these curves, since the impulse response is the limiting factor.

Curves III and IV: Two-section RC filter. $T = 7$.

Note: Interference is largely quasi-steady-state and greater transmitter filtering either by reducing T or increasing the number of filter sections will have very little effect on R .

⊗ : Experimental points.

Line V: Limitations in R for frequency separation greater than 15 kc/s are caused by limitations of maximum receiver selectivity.

SECTION B

RECEPTION

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98	Choice of intermediate frequency and protection against undesired responses of super heterodyne receivers	41
99	Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	43
100	Tolerable receiver frequency instability	49
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The following Reports, classified in other Sections, also concern Reception:

Report No.	Section
105	C
106	C
107	C
119	E



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REPORT No. 98 *

**CHOICE OF INTERMEDIATE FREQUENCY AND PROTECTION AGAINST
UNDESIED RESPONSES OF SUPER-HETERODYNE RECEIVERS**

(Question No. 171 (II))

(Warsaw, 1956—Los Angeles, 1959)

1. Contributions relating to Question No. 171 (II) have been received in Docs. Nos. 6 and 157 of Warsaw, 1956, in Docs. Nos. II/I, II/4, II/13 and II/20 of Geneva, 1958, and Doc. No. 138 of Los Angeles, 1959.

2. The study of this subject has now reached a stage where the following statements can be made:

2.1 The principal factors contributing to the production of undesired responses of super-heterodyne receivers are inadequate image and intermediate-frequency response ratios and the generation of intermediate-frequency and frequency-change oscillator harmonics. Measured values of the undesired responses occurring in receivers of various types are given in the above-mentioned documents.

2.2 In the case of long-wave, medium-wave and short-wave sound broadcast receivers, the only method of improvement not requiring an undue increase in cost is the choice of a suitable value of intermediate-frequency; no single value of intermediate-frequency is completely satisfactory for all parts of the European zone. Intermediate frequencies in the range of 420 to 475 kc/s are commonly used. No specified value for the intermediate frequency can be recommended, because it will be of advantage to be able to avoid interference by convenient choice of intermediate frequencies according to the different situations with respect to powerful transmitters operating in these bands. Self generated beats and whistles can be avoided by conventional technical means with any of the above-mentioned values. For receivers of high quality the problem need not be considered, as an adequate IF and image rejection is always assured.

2.3 For domestic frequency modulation receivers, the intermediate frequency of 10.7 Mc/s, normally used, is satisfactory provided that radiation by the receiver on the IF and its harmonics and at the frequency of the local oscillator and its harmonics, is sufficiently reduced.

2.4 In the case of monochrome television receivers, working in Bands I and III, there seems to be a general trend towards a national standardization of the IF channel. As several television systems are in use, and since for any one system there are different channel allocations in different countries, it seems impossible to propose only one preferred IF. Preferred values of intermediate frequencies in different countries for monochrome television receivers are shown in the table below:

* This Report which replaces Report No. 41, was adopted unanimously.

Number of lines for picture (frame)	Country	Channel limits at intermediate frequency (Mc/s)	Intermediate frequency	
			Sound-channel f_s (Mc/s)	Video-channel f_v (Mc/s)
405	United Kingdom	33.4–38.4	38.15	34.65
525	United States	41–47*	41.25	45.75
	Japan	22–28**	22.25	26.75
625	Spain Netherlands Fed. German Rep. Switzerland	33.15–40.15	33.4	38.9
	Italy	40–47**	40.25	45.75
	U.S.S.R.	27.5–35.5	27.75	34.25

* According to Electronic Industries Association Standard Rec. No. 109 C.

** Protected band.

Note: This Table includes data provided at Geneva (1958) and Los Angeles (1959) and will be completed in the future.

With the exception of some particular geographical regions, taking into account the limited range for VHF and UHF transmitters, the general situation does not seem to be critical. No new points of view are expected with respect to the choice of IF. Anyhow, other technical means are already applied and used in the common techniques to avoid external and internal interference, so that practical results are quite satisfactory. It seems, therefore, to be reasonable to finish the studies for these types of receiver as given under § 2.2, 2.3 and 2.4.

2.5 In receivers for point-to-point services of high quality, no difficulties are to be expected with a value of IF rejection of about 70 to 80 db and good shielding of the whole equipment.

2.6 For receivers for multi-channel radio-relay systems in the VHF, UHF and higher frequency bands, the problem of the choice of IF is mainly one of standardization with respect to interconnection at intermediate frequency and not only a problem of avoiding interference. These studies will be undertaken by Study Group IX.

2.7 For mobile receivers it is difficult to relate the choice of intermediate-frequency to geographical locations, since such receivers may be required to operate in the vicinity of any one of a large number of transmitters. Double super-heterodyne reception is often employed in mobile receivers operating in the VHF range to obtain good image rejection. In the case of marine mobile receivers, the commonly used intermediate frequencies of 420 to 475 kc/s are clearly unsuitable for receivers required to operate in the 500 kc/s maritime band, and higher values of IF, e.g. 530 to 700 kc/s, are used. The results of watches in this frequency band (530-700 kc/s) show that the chosen intermediate frequencies for maritime mobile receivers are often very close to the fundamental frequencies of high power (100 kW or more) broadcast transmitters. In certain maritime areas of high density traffic this results in interference which could be serious if occurring during distress traffic.

3. As a result of the considerations given above, further studies of the choice of IF are necessary in the case of maritime mobile receivers. (See Question No. 171 (II)). It might be necessary in the future to continue the studies for bands other than those in § 2.4. If necessary, a new Question would have to be prepared.

REPORT No. 99 *

USABLE SENSITIVITY OF RADIO RECEIVERS IN THE PRESENCE
OF QUASI-IMPULSIVE INTERFERENCE

(Question No. 175 (II))

(Los Angeles, 1959)

1. As mentioned in Recommendation No. 159, the expression “quasi-impulsive interference” can be interpreted in different ways.

Here, we mean that kind of interference which is *intermediate* between the two extreme cases of:

- *thermal noise* or “white noise” of very irregular shape and amplitude, with pulses following one another so that their effects in the receiver are more or less overlapping;
- *true impulsive* interference, made of successive pulses, the duration of which is shorter than the time constant of the receiver, with intervals long enough to prevent their effects from overlapping.

The two main types of quasi-impulsive interference are *atmospheric noise* and *man-made noise*, such as the ignition of internal combustion engines, disturbances from switches, electric motors, high-frequency plastic-welding machines, etc. The man-made noise may, for certain periods of time, occur quasi-periodically, with fairly constant shape and amplitude.

Such interference requires special methods of measurement, and the calculation of its effects on the receivers is difficult.

2. *Atmospheric noise* has been studied for many years. A few recent papers are listed in the bibliography below. (See also Recommendation No. 315 Report No. 65, Study Programmes Nos. 128 (III) and 154 (VI).) They show that it is possible, at a given time, in a given place, on a given frequency, with a given bandwidth and a given detector and recording instrument time constant, to measure and record certain characteristic quantities;

- average power for a long time (for example, hourly) interval;
- variations of envelope amplitude and/or the time rate of these variations.

These variations can be presented in terms of amplitude distribution (for example, cumulative) and time or frequency distribution; they can also be analysed in terms of r.m.s., average, median, peak, quasi-peak, or mean logarithmic values. Calibration may be referred either to absolute field strength of intensity, or by ratio to the thermal noise level.

3. Numerous curves of such distributions have been given [1, 2, 4, 5, 7]. One can try to approximate them by simple mathematical laws, a few of which are listed in the attached Annex. But these laws are only approximate. The important point is that, although the Rayleigh law is more or less correct for the lower levels of natural interference (which are exceeded during most of the time), it is completely wrong for strong interference, which occurs rarely or for short periods of time; the probability of “strong quasi-impulsive noise” decreases much more slowly. The dynamic range of natural noise is therefore much greater than that of thermal noise. Hence, as the majority of radiocommunications require a very low error probability (e.g. 0.10%) they are still appreciably disturbed by rare and very strong noise, and, at such levels, the curves show** that an increase in the signal intensity has little effect (much less than with thermal noise).

* This Report was adopted by correspondence without reservations (see page 9).

** The curves are not always drawn sufficiently far in the region of low probabilities, which is easily explained by the difficulty of measurement, but which is also very regrettable, as this is precisely the most interesting region from the practical viewpoint.

4. Studies have also been made of the variation of noise power over the frequency spectrum. In general this variation is slow, so that the portion of the spectrum within the passband of a narrow band receiver may be considered uniform ("white-noise"). For wider passbands this would not hold especially as the frequency limits for ionospheric propagation are approached.

5. It can be concluded that the mean energy produced in a receiver by natural noise must be proportional to the bandwidth B ; the r.m.s. voltage is therefore proportional to $B^{0.5}$.

This appears to be confirmed by general experience. But it does not necessarily follow that the other characteristic values, and ultimately the effect on the receiver, are also proportional to $B^{0.5}$.

A review of the observations made ((1), § J) shows that the mean voltage often increases more slowly with B , for example:

- According to the U.K., if $B > 0.3$ kc/s $B^{0.33}$ to $B^{0.25}$
- According to Florida University, U.S.A. $B^{0.34}$
- According to the N.B.S., U.S.A., ((1), Fig. 20) $B^{0.42}$
- According to the N.B.S., the mean logarithm increases approximately with $B^{0.35}$.

The influence of bandwidth on amplitude distribution can be calculated [6].

Finally, the effect on the receiver may vary in accordance with quite a different law. Specifically, if there is a limiter, it can be found ((2) p. 10) that an increase in the bandwidth *decreases* the harmful effect of the noise. This had been foreseen and is easily explained by the fact that the narrowing of the passband decreases the amplitude of the noise, but prolongs its duration. However, if this selection is followed by effective limiting, the amplitude cannot exceed a fixed threshold and need no longer be considered. It is more desirable therefore to reduce its duration, and for this it is necessary to widen the band.

6. Hence, assuming that natural noise is a known factor, the next stage is to calculate its effect upon a receiver, and in particular the error probability on a signal of a given type (for example, teletypewriter) arriving on a fixed level.

This can be done in two stages;

6.1 Probability of error on an isolated element of a binary code. It has been shown and verified that, for frequency shift reception, this probability is equal to *one-half* the probability of the corresponding level on the noise envelope (((2), pp. 21, 24, 25 and (4)).

6.2 Probability of error on a character containing a given number of binary elements. For example, with the 5-unit code, if each "unit" is affected by the probability of error " p " and if these probabilities are independent, the probability of error on a character is ((2), p. 23):

$$\begin{array}{l} \text{In synchronous working: } P = 1 - (1 - p)^5 \approx 5p \\ \text{For a start-stop system: } P \approx 1 - (1 - p)^{17} \approx 17p \end{array} \left\{ \begin{array}{l} \\ \end{array} \right. \text{(if } p \text{ is small)}$$

The case of a variable signal level may then be considered. It has been found [2] that the lower the admissible error rate the more troublesome the fading. In a specific case, the signal's useful field had to be multiplied by 1.6 with 10% error and by 5.0 with 0.1% error.

7. Nevertheless, the analysis has revealed another factor which is not as predictable as for thermal noise, i.e., the *variation rate*, expressed as;

- the number of times per second the envelope curve cuts the mean value;
- the individual duration probability of each noise impulse;
- the probability of a given spacing between two successive noise impulses.

The two latter intervals should be compared to the duration of the signal element.

Let us consider, for instance, the case of 3 or 4 successive noise impulses whose individual durations (including any lengthening by the receiver's time constant) are slightly shorter than that of a signal element.

If they arrive with a spacing sufficient to affect different characters, they will interfere with them all and give rise to 3 or 4 wrong characters. If, on the contrary, they are due to the same cause and are grouped together in the course of a character's duration (including its synchronization), only that character will be wrong. For instance, it has been shown [2] that if two elements of the signal are systematically covered by the noise impulses, the error on characters is reduced to:

$$P' \approx 1 - (1 - p)^7$$

$$\approx 7p \text{ (if } p \text{ is small).}$$

Thus the signal speed may exert an influence even if the receiver's passband remains the same.

8. The analysis may be extended to different types of receiver and modulation (e.g. amplitude, frequency shift, etc.).

Thus ((2), Table I) a receiver system may be characterized by a "system performance factor" (S.P.F.) equal to the transmission speed divided by the signal/noise power ratio required for a given error probability. It is conveniently expressed in decibels by:

$$\text{S.P.F.} = 10 \log_{10} W - 20 \log_{10} (c/n)$$

where W = speed in words/minute.
 c = r.m.s. signal voltage.
 n = r.m.s. noise voltage in a 1 kc/s effective bandwidth.

Note: The value of S.P.F. decreases as the value of the error probabilities decreases.

It is observed that these values and their rate of decrease depend on the receiver, the code used and the type of noise. For example, for a certain type of automatic FSK teleprinter receiver, the maximum S.P.F. is 17.8 db and 14.8 db for 10% error, with thermal and atmospheric noise respectively. If the admissible error rate is reduced to 0.1%, the S.P.F. decrease but little (from 17.8 to 15.8 db) in the presence of thermal noise, while the decrease is much more marked in the presence of atmospheric noise (from 14.8 to 6.8 db). In other words, to reduce the error probability from 10% to 0.1% it suffices to increase the signal by 2 db in the first case, while in the second case, it must be increased by 8 db.

The part played by "frequency shift" and its optimum value [2], might likewise prove to be important.

In manual Morse telegraphy with aural reception, for an accepted letter error rate of 10% the performance factor is 12.8 db for thermal noise and ranges from 13 to 22 db for atmospheric noise. The presence of a human operator, however makes it very difficult to reduce the error rate to below 1%.

9. Studies carried out over many years have made it possible to assess the atmospheric noise distribution at the surface of the earth, as well as its variations with the hour of the day, season, ionospheric disturbances, etc. However, until recently, only the variations in the absolute level have been considered. Changes in the distribution of amplitude, variation rate, etc., have recently been reported [5, 7] and further work is being continued.

10. In conclusion, although quasi-impulsive atmospheric noise may be studied statistically like thermal noise, there is a sufficient difference between the two to warrant widely different, and often divergent methods for reducing the effects of the former:

- its "dynamic range" is much larger; consequently, the reduction of errors by raising the signal level is much less effective in this case;
- the number of errors depends not only on the statistical amplitude distribution but also on the variation rate, i.e. the individual duration and the spacing of the noise signals in relation to the duration of the signal element; the variation rate has a marked effect even independently of the bandwidth of the receiver; *

* This would also be true with thermal noise if fading is present.

- the method of reducing the effect of quasi-impulsive interference by reducing the RF bandwidth is less effective; with a good limiter, it may even be advantageous to increase the bandwidth.

The effect of such noise on telegraph receivers can be calculated in a satisfactory way and such receivers can be classified according to their "performance factor".

11. As regards *man-made noise*, we must recall that a great deal of study has been devoted to the problem, particularly by the C.I.S.P.R. However, the point of view of that organization may differ from that of the C.C.I.R., particularly because the C.I.S.P.R. is primarily interested in broadcasting and usually considers one source of interference at a time.

Nevertheless, some of the contributions submitted contain observations and conclusions of a general nature on these types of noise and the effect they produce, which may be useful in providing a reply to Question No. 125. * The comments may be summarized as follows:

12. Many but not all types of man-made interference considered may be regarded as short pulses, more or less constant in amplitude (or at least, subject to no more than slight variations) repeated at a fairly regular rate governed by the nature of the interfering equipment.

The repetition rate N may be very low, e.g. a fraction of a c/s; or of the order of industrial frequencies, e.g. 50 or 60 c/s; or, again, higher than that, although rarely exceeding a few kc/s, i.e. the receiver's passband B . The result is that the duration T of each interfering pulse is, in practice, usually very short compared with the interval between two pulses.

It is likewise usually assumed (this is debatable in the case of television or radar) that the duration T is shorter than or equal to the reciprocal of the bandwidth B of the receiver.

This being so, the disturbance produced in a receiver tuned to a frequency F_0 can be calculated with only two parameters, i.e.

- the peak value P of a single frequency component of the interfering impulses at or near the frequency F_0 ;
- the repetition rate N .

It is found, for instance [9] that in a linear receiver with a gain G , each separate pulse produces a damped oscillation with a peak amplitude $U_{max} = G.P.B.$, reducing to half this value after a time $1/B$. This peak amplitude U_{max} is therefore the first factor to be measured when defining the interfering signal; if it varies, the mean value is taken.

The second characteristic parameter, i.e. the repetition rate N , can be easily determined by direct reading, e.g., on an oscilloscope. It governs the extent of the nuisance caused in practice in a way which varies in complexity with the nature of the signal. In telegraphy, the relation between N and P and the number of character errors can usually be calculated. The calculations may be extended to cases where there is a limiter and where the bandwidths before and after limiting are known.

13. "Standard interference generators" can be designed—and, in fact, exist already—for providing pulses with levels and rates that are adjustable and known, or random. They have been used to simulate the effects of non man-made noise [10].

14. The experimental measurement conditions required for evaluating and comparing the interfering signals from various sources of disturbance can be defined, and the extent to which they can be reduced through "interference suppressors" can be measured [9, 10] and other C.I.S.P.R. documents.

15. It has been suggested [8] that the effect of a continuous wave with a rapidly varying frequency, sweeping quickly through the receiver's passband, may be likened to a shock and regarded as a short interfering signal of the type dealt with in § 12. This phenomenon, which is liable to arise with certain machinery using high frequencies, is worthy of further study.

16. On the basis of the above considerations the following partial reply may be given to Question No. 125 *:

* This Question has been replaced by Question No. 175 (II).

Point 1. — The usable sensitivity of receivers may be reduced by quasi-impulsive interference in any service, depending on local conditions and the frequency range used.

Point 2. — The response of telegraph receivers to such interference can be calculated by measuring certain characteristics, e.g.:

<i>Atmospheric noise and man-made noise</i>	<i>True impulsive (non-overlapping) man-made noise</i>
— envelope amplitude distribution	— amplitude of individual pulses and their duration and wave shape
— duration and spacing distributions and their variation rates	— repetition rate

The calculation is much more difficult for voice receivers.

Point 3. — Pulse generators can be used for simulation of some types of man-made noise [10]; but, as regards atmospheric noise, the Poisson distribution provides a poor approximation, and it is better to simulate the real characteristics mentioned in Point 2 or to use magnetic tape recordings with special techniques.

Point 4. — It would seem that, to define the response of receivers to quasi-impulsive interference, one should obtain the signal/noise ratio required to ensure a given transmission speed with an error probability not exceeding a certain limit.

Sets of figures corresponding to different error probabilities, e.g. from say 10% to 0.01%, would serve a useful purpose.

An indication should be given of the type of noise considered together with its characteristics (amplitude and duration distribution and spacing), since different types of noise will yield different types of error curves.

Point 5. — The maximum admissible interference level can only properly be calculated after performing the analysis described under Point 4.

Point 6. — The impulse-limited sensitivity will be a function of:

- the type of noise
- the noise level
- the receiver characteristics
- the error rate desired;

it could range from 1 db or less above the r.m.s. noise level to 60 db or more above the r.m.s. noise level.

BIBLIOGRAPHY

1. U.R.S.I. C.R. XIITH ASSEMBLY, BOULDER 1957, Vol. XI, fasc. 4, Comm. IV (Crichlow Report).
2. WATT, COON, MAXWELL, PLUSH. The Performance of Some Radio Systems in the Presence of Thermal and Atmospheric Noise. *P.I.R.E.*, 46, 1914-1923, (December 1958).
3. WATT, COON, ZURICH. National Bureau of Standards, Report 5543, 1957, refers to S.P. No. 43, rather than to Question No. 125.
4. Doc. 30 (Japan), of Los Angeles, 1959.
5. WATT and MAXWELL. Measured Statistical Characteristics of VLF Atmospheric Radio Noise. *P.I.R.E.*, 45, 55-62, (January 1957).
6. FULTON, F. F. The Effect of Receiver Bandwidth on Amplitude Distribution of VLF Atmospheric Noise. *Symp. propagation of VLF radio waves, Boulder, Colo.*, 3, 37-1, 37-19, (1957).
7. HARWOOD. Atmospheric noise at frequencies between 10 kc/s and 30 kc/s. *Proc. I.E.E.*, 105, part B, 293-300, (May 1958).
8. Doc. 166 (France) of Los Angeles, 1959.

9. C.I.S.P.R. Doc. R.I. (France) 204, August 1953 (FROMY, E. Mesure du pouvoir perturbateur d'un matériel électrique prototype).
10. C.I.S.P.R. Doc. R.I. (France) 206, August 1953 (FROMY, E. Les perturbateurs étalons).
11. Docs. 101 and 147 (U.S.S.R.) of Los Angeles, 1959.

ANNEX

FORMULAE FOR AMPLITUDE DISTRIBUTION

An attempt can be made to represent amplitude distributions by simple mathematical laws and graphs on which the laws appear as straight lines.

where v is the envelope voltage, v_m its median value and $\bar{v}$ its average value.

1. Rayleigh law.

The overall probability of having a voltage higher than v is:

$$Q(v) = 1 - \exp\left(-0.693 v^2/v_m^2\right)$$

The scales of a graph can be so chosen as to give a straight line (Fig. 1) ([1] Fig. 11-15) [2]. This is the case for thermal noise.

2. Log-normal distribution.

Putting $x = \log \frac{v}{\bar{v}}$, the probability of an amplitude comprised between v and $(v + dv)$ is:

$$q(v) \cdot dv = \frac{1}{\sqrt{\pi}} \exp(-x^2) \cdot dx$$

and the overall probability of an amplitude greater than v is

$$Q(v) = \int_v^{\infty} q(v) dv$$

which can also be represented by a straight line if the ordinates are Gaussian ([1], Fig. 9-10).

3. Law

$$Q(v) = \left[1 - (2 v/\bar{v})^q \right]^{-1}$$

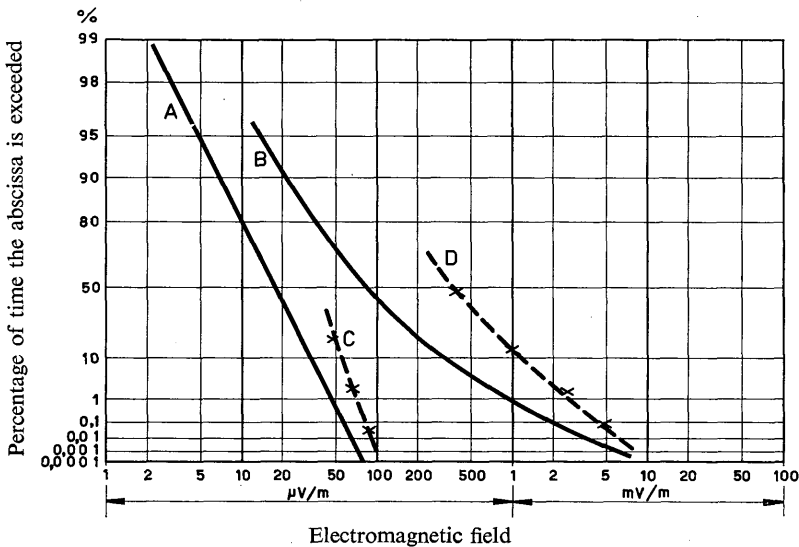
q being an experimental constant

4. Law

$$Q(v) = \exp(-y^2)$$

where
$$v = a_1 y + a_2 y^{\left(\frac{b+1}{2}\right)} + a_3 y^6$$

and
$$b = 0.6 \left[20 \log_{10} (v_{eff}/\bar{v}) \right]$$



Comparison of thermal and atmospheric noise

A: Thermal noise envelope.	C: Errors due to thermal noise.
B: Atmospheric noise envelope.	D: Errors due to atmospheric noise.

REPORT No. 100 *

TOLERABLE RECEIVER FREQUENCY INSTABILITY

Question No. 173 (II)

(Los Angeles, 1959)

Two documents—Doc. II/2 (Federal Republic of Germany) and II/24 (United Kingdom)—concerning operative § 4 of Question No. 173 (II) have been submitted to the 1958 Geneva interim meetings. In particular, Doc. II/24 gives a table listing the required stabilities for different kinds of receiver.

A systematic study of permissible instability seems desirable on the basis of the documentation already available: Recommendation No. 233 on transmitter frequency stabilization, Recommendation No. 235 on receiver selectivity and Recommendation No. 236 on receiver stability. More particularly, the values given in Recommendation No. 236 should be compared with the values actually required.

Values which are of interest could be tabulated in the form given in the Annex which gives an example of such a document based on the given in particular in Table III of Doc. No. II/24, (United Kingdom) of Geneva, 1958.

In Doc. No. II/2 (Federal Republic of Germany), it is stated that: “The maximum tolerable frequency instability depends essentially on the class of emission used, which in turn determines the necessary pass-band of the filters which follow the frequency change. It can be assumed as a general rule that the central frequency of the signal in such filters cannot differ from its nominal frequency by more than 20% of the passband. This tolerance must be obtained either by manual or automatic tuning or by appropriate frequency correction. For receivers of single sideband emissions, this will depend essentially on the narrowband filter for the carrier. For receivers of F1 or F6 emissions (duplex systems, Recommendation No. 247) the frequency instability of the oscillators should not be more than 10% of the frequency deviation.”

* This Report was adopted by correspondence without reservations (see page 9).

ANNEX

R 100

— 50 —

1	2	3	4	5	6	7	8	9	10	11	12
Class of Emission	Service	Range	Typical Frequency (Mc/s)	Relative Stability of Transmitter (Rec. 233) ($\times 10^{-6}$) ⁽²⁾	Bandwidth at 6 db (Rec. 235) (kc/s) ⁽²⁾	Mean Measured value of Stability (Rec. 236)		Value proposed for the maximum permissible receiver drift from the typical frequency (1)		Time during which the stability in columns 9 and 10 is required (hours)	Remarks
						($\times 10^{-6}$) ⁽²⁾	Times between which drift was measured (after switching on) (mins) ⁽²⁾	Drift (+ kc/s)	Relative drift ($\times 10^{-6}$)		
A3	Broadcasting	M.F. H.F.	1 20	10 15	5.5 8	170 80	10-120 10-120	1 1	1000 50	2 2	
F3	Broadcasting	V.H.F.	100	20		220	10-120	15	150	2	
A5 (405 lines)	Broadcasting	Band I Band III	50 200	50 50		300 300	10-120 10-120	100 100	2000 500	2 2	
A3b	Fixed telephony	H.F.	20	15	6.5			0.01	0.5	10	Crystal or a.f.c.
A3 (50 kc/s between channels)	Mobile telephony	V.H.F.	80 160	50 20	35 35	5 5	10-120 10-120	10 10	120 60	As long as the receiver is in use	Crystal
F3 (50 kc/s between channels $\Delta F = \pm 15$ kc/s)	Mobile telephony	V.H.F.	160	20	35	5	10-120	5	30		
A1	Fixed telegraphy	L.F. H.F.	0.1 20	1000 50	0.2 ⁽³⁾ 0.4			0.02 0.05	200 2.5	10 10	Crystal or a.f.c.
F1	Fixed telegraphy	H.F.	20	50				0.01	0.5	10	Crystal or a.f.c.
A1, A2	Maritime telegraphy	M.F.	0.5 0.5	200 200	3.2 3.2			0.3 1	600 2000	10 0.1	
		H.F.	20 20	200 200	1.4 1.4	4 70	60-120 1-10	0.3 1	15 50	10 0.1	

(1) This table deals only with the drift in time. In the case only of receivers in use continuously over long periods, the value indicated in this case for the maximum permissible drift should include the drift due to moderate changes in climate. Theoretically, the receiver should remain in tune (within the permitted tolerances) for the number of hours shown, computed from the instant when they are sufficiently warmed-up to furnish a suitable output signal. In practice one may allow, for broadcast receivers, a warming-up period of about 5 minutes; for fixed service receivers, this period may be longer, for example, a quarter of an hour.

(2) To be modified in accordance with further Recommendations as issued by Study Groups concerned.

(3) This figure is not given in Recommendation No. 236.

REPORT No. 101 *

FREQUENCY STABILITY OF RECEIVERS

**Stability of I.F. amplifiers with electro-mechanical filters, semi-conductor capacitors
and ferromagnetic tuning**

(Questions Nos. 173 (II) and 174 (II))

(Los Angeles, 1959)

1. 1.1 Electro-mechanical filters in I.F. amplifiers ensure high selectivity combined with small dimensions which give rise to a rapid increase in their use in receivers.

1.2 The application of semi-conductor diodes and transistors as variable capacitors and inductors with ferrite cores as variable inductors (ferromagnetic tuning) makes it possible to reduce the dimensions of resonance circuits and to permit tuning and adjustment of the passband by changing the control voltage.

1.3 It is of great interest to determine the characteristic values of tuning stability of receivers having the above mentioned elements.

2. Some documents have been submitted to the IXth Plenary Assembly of the C.C.I.R. which give some information on this subject (Docs. Nos. 110, 121, 123 and 137 (U.S.S.R.) of Los Angeles, 1959).

3. According to the preliminary information received:

3.1 The coefficient of temperature dependence on frequency for electro-mechanical filters is of the order 2×10^{-6} to 5×10^{-6} .

3.2 The temperature stability of filters with semi-conductor diodes and transistors used as capacitors might not be worse than the stability of filters using ordinary capacitors and there are ways of improving it.

3.3 The temperature stability of filters with ferromagnetic tuning is at present worse than that of other types of filters, with conventional coils.

4. Because of insufficiency of information, further study is considered necessary and forms the subject of Questions No. 173 (II) and No. 174 (II).

* This Report was adopted unanimously.

REPORT No. 102 *

SPURIOUS EMISSIONS FROM RECEIVERS OF SPECIAL TYPES

(Question No. 176 (II))

(Los Angeles, 1959)

Examination of Geneva Doc. No. II/7 (Italy), Geneva, 1958, indicates that:

1. Methods established by the I.E.C. and, in general, by national authorities, for measuring radiation from broadcast and television sets are not suitable for special types such as high grade HF communication receivers.
 2. For special cases such as those quoted above, radiation is reduced sufficiently so as not to produce perceptible interference even when a large number of such sets is in operation in close proximity to each other.
 3. As there is not sufficient information available for other types of receivers, further studies are necessary.
-

REPORT No. 103 *

**RECOMMENDED METHODS FOR MEASURING AMPLITUDE MODULATION
SUPPRESSION IN FREQUENCY MODULATION RECEIVERS**

(Question No. 177 (II))

(Los Angeles, 1959)

1. Docs. Nos. II/8 (Italy) and II/22 (United Kingdom) of Geneva, 1958, both recommended the use of a direct-reading method for measuring amplitude modulation suppression in frequency modulation receivers, in preference to an oscilloscopic method.

Suitable direct-reading methods are described below.

2. The preferred direct-reading method uses simultaneous frequency and amplitude modulation. Since, in practice, an average percentage of modulation of 30% is rarely exceeded for both frequency and amplitude modulation transmissions, this value of 30% is recommended for test purposes for both types of modulation.

* This Report was adopted unanimously.

Additional measurements with higher values of frequency deviation (e.g. up to 100%) can be made.

2.1 As the modulation frequencies used affect the selectivity required in the measuring equipment, a frequency lower than the I.E.C. value of 400 c/s is preferable for frequency modulation and a value of 100 c/s is recommended. The frequency used for amplitude modulation is preferably 1000 c/s.

2.2 The equipment used for measuring output power should be preceded by a filter which sufficiently attenuates the fundamental and harmonics of the frequency modulation as well as hum, and passes frequencies between 500 c/s and 3000 c/s * with little attenuation.

Alternatively, a wave analyser can be used to measure the components of the output separately.

2.3 Initially, the signal is frequency modulated at 1000 c/s and the receiver output adjusted to a convenient value; the simultaneous frequency and amplitude modulations described above are then applied and the output again measured; the ratio of the first measured value to the second is the AM suppression ratio.

The effect of tuning should be checked and if it is critical, measurements at more than one tuning position should be made, the change in tuning being recorded.

3. An alternative method uses frequency modulation and amplitude modulation applied sequentially to the carrier, the frequency being 1000 c/s in both cases. The output under these two conditions is measured and a filter may be necessary to remove hum.

3.1 For each channel tested, measurements should be made on at least three radio frequencies; these should be the tuning frequency and frequencies 30 kc/s above and below it.

4. It is recommended that tests should be made with at least three input levels: the values —80 db, —60 db and —40 db (reference 1 mW) are suggested.

A fourth input level, at which it has been recommended that measurements be made in the threshold level, defined as 13 db greater than the effective noise value $FkTB$, F is the noise factor and B is the pre-detection bandwidth.

5. It is reported that under normal conditions of reception the distortion due to multipath propagation can be substantially eliminated over a small range of tuning if the AM suppression ratio is at least 35 db, measured by the method described in § 2, or at least 30 db, measured by the method described in § 3, at each of the three carrier frequencies separated by 30 kc/s.

* See Doc. No. 212 of Los Angeles, 1959, which contains other suggestions for appropriate filters.

REPORT No. 104 *

**METHODS OF MEASURING PHASE/FREQUENCY
OR GROUP-DELAY/FREQUENCY CHARACTERISTICS OF RECEIVERS**

(Question No. 178 (II))

(Los Angeles, 1959)

Question No. 178 (II) "Selectivity of receivers" relates to appropriate methods of measuring the phase/frequency or group-delay/frequency characteristics of receivers. It has been recognized that these characteristics are important in connection with the quality of reception in receivers for television programmes and for HF telegraphy at high keying speeds.

Some documents have already been supplied to the C.C.I.R. reporting the measuring methods and apparatus for such receivers. The documents and the brief descriptions of the methods and apparatus are as follows:

1. For television receivers.

1.1 Doc. No. 257 (Netherlands) of Warsaw, 1956: a direct reading method of measuring group-delay/frequency characteristics is reported. In the apparatus described, by employing a special phase detection valve as a phase meter, the characteristics can be observed on the screen of a cathode-ray oscilloscope. By using this apparatus in combination with a signal generator which has an automatic frequency sweeping device, the group-delay/frequency characteristics of intermediate frequency amplifiers of television receivers can be measured with an accuracy of one milli-microsecond.

1.2 Doc. No. 488 (Federal German Republic) of Warsaw, 1956: three methods are described in this document for the measurement. There is a slight difference between the three methods, but the principle is almost the same. The measurements are made by using two signal generators of an ordinary type. Thus the phase/frequency characteristics can be measured without providing any special signal generator. The phase-delay is read on a phase indicator.

2. For high-frequency telegraph receivers.

Doc. No. II/15 (Japan) of Geneva, 1958: a method and a special apparatus for measuring the time-delay/frequency characteristics of intermediate frequency amplifiers in radio telegraph receivers are introduced. It is well known that the intermediate frequency stages have a predominating effect, especially in receivers used for high speed radio telegraphy operated with frequency shift keying. The apparatus is of the direct reading type and uses special signal generators which have automatic frequency sweeping devices, thus the time-delay/frequency characteristics can be observed directly on a cathode-ray oscilloscope.

Those methods and apparatus described in the documents mentioned above can give useful information. Nevertheless, the amount of information obtained is not sufficient to permit a decision on a standard method and apparatus for the measurement of phase/frequency or group-delay/frequency characteristics of receivers. Therefore, further contributions are invited from Administrations for studies to permit a decision on standard methods and apparatus.

* This Report was adopted unanimously.

SECTION C

FIXED SERVICES

No.	Title	Page
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42	Use of radio-circuits in association with 5-unit start-stop telegraph apparatus	58
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106	Improvement obtainable from the use of directional antennae	64
107	Directivity of antennae at great distances	69
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The following Reports, classified in other sections, also concern the Fixed Services:

Report No.	Section
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96	A
129-137	F



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REPORT No. 19 *

VOICE-FREQUENCY TELEGRAPHY ON RADIO CIRCUITS

(Question No. 43 (III))

(London, 1953)

The C.C.I.R. in answer to Question No. 43 (III) has carried out certain studies concerning voice-frequency telegraphy on radio circuits.

These studies have shown that it is not yet possible to give a complete answer to the question. However, as regards radio circuits using frequencies below 30 Mc/s, a recommendation has been made dealing with diversity reception. Moreover, the C.C.I.R. would draw the attention of the C.C.I.T.T. to the following points in respect of reception below 30 Mc/s:

1. the voice-frequency system which radiates one frequency for one signalling condition and suppresses the radiation for the other signalling condition does not give satisfactory results when applied to radio circuits;
2. systems which radiate one frequency for one signalling condition and a different frequency for the other signalling condition (using two oscillators or one frequency-shift oscillator) have in general to be modified for this special use. For instance:
 - the range of linear amplification of the audio amplifier common to all channels in the receiving equipment has to be much greater than is necessary on land-line circuits because of the large changes in amplitude of the received signals due to fading;
 - for the same reason the limiter preceding each channel discriminator should operate over a large range of input signal amplitudes;
 - many filters used in equipment designed for land-line circuits do not have suitable characteristics;
 - to obtain good diversity results it is not sufficient merely to connect the outputs of separate channels of standard voice-frequency equipment in series or in parallel, but special provisions have to be made;
3. notwithstanding all precautions taken, it should be realised that the use of voice-frequency equipment on radio circuits may become impossible when reception conditions are poor.

* This Report was adopted unanimously.

REPORT No. 42 *

USE OF RADIO CIRCUITS IN ASSOCIATION WITH 5-UNIT
START-STOP TELEGRAPH APPARATUS

(Study Programme No. 128 (III))

(London, 1953 — Warsaw, 1956)

The principal factors determining the error rate in a radiotelegraphy transmission arise from the fact that:

- radio propagation is essentially variable,
- unwanted signals caused by noise or interference appear at the receiving end.

1. As a result of variations in propagation a complex signal is supplied to the receiver, consisting of superimposed signals from several transmission paths, with, in certain cases, widely different delays, the paths providing attenuation and phase characteristics varying with frequency. As a result the telegraph signal appearing at the output of the demodulator suffers random distortion, which becomes more pronounced as the telegraph speed increases, the rounding of the signal emitted possibly being also a contributory factor.

2. When this complex signal is further disturbed by noise or interference of any sort, two phenomena occur simultaneously: modification of the distortion of the demodulated signal and the appearance of telegraph signals alien to those of the original modulation.

Whereas, at least for relatively low speeds (50 bauds), the distortion due to propagation phenomena (§ 1) has a limited amplitude and rarely, in itself, gives rise to errors in translation, the attenuation of the signals received emphasises the effect of the unwanted signals. This effect can be reduced by increasing the transmitter power.

Consequently, the signals received seem in general to undergo a natural random distortion which cannot be reduced below a certain threshold by increasing the transmitter power, whereas such a measure does in general make it possible to lower the error rate.

An element to be considered in assessing the expected quality of a given code is the correlation existing between the instants of appearance of incorrect signals, which depends firstly on the type of noise or interference in question and secondly on the variable characteristics of propagation.

A further factor to be considered is the improvement resulting from diversity reception, taking into account the combination method thereof.

In the case of relatively high telegraph speeds (200 bauds), when the appearance of errors may correspond with an increase in the distortion of the signal received, synchronized systems are more reliable because of the wider margin they provide.

In the case of lower speeds, the chief disadvantage of start-stop systems lies in the risk of a transient loss of synchronism during the mutilation of a start or a stop signal.

* This Report, which replaces Report No. 30, was adopted unanimously.

REPORT No. 105 *

BANDWIDTHS AND SIGNAL-TO-NOISE RATIOS IN COMPLETE SYSTEMS

The prediction of telegraph system performance in terms of bandwidth
and signal-to-noise ratios

(Study Programme No. 128 (III))

(Los Angeles, 1959)

Study Programme No. 128 (III) sets out some questions the answer to which would form a basis for the evaluation of the performance of complete systems. The questions are in general too vague for any positive information to be gained from them as they include terms like "excellent service" the interpretation of which depends greatly on the type of traffic the system is intended to carry out and the grade of service. This paper attempts to give a basis for a more objective method of performance specification in the light of recent work on telegraph systems.

Theoretical studies of the mechanism of detection of telegraph signals in the presence of noise, having a Gaussian distribution [1] have made it possible to define the performance of a system, in terms of the element error rate, as a function of the signal-to-noise ratio just prior to the detector. The word detector is used here in a very general sense and the detector might be a limiter-discriminator. It is convenient to use a quantity called the "normalized signal-to-noise ratio" which is defined as the signal-to-noise power ratio per baud per unit bandwidth, or the ratio of the signal power to the noise power per unit bandwidth divided by the number of bauds. Direct comparison between different receivers working at different speeds is therefore possible.

In the studies it was also found possible to specify the performance of a telegraph receiver by a single parameter. This parameter has been called the 'demodulation factor' and it is the amount (in db) by which the signal-to-noise ratio (normalized) applied to the receiver under test exceeds that applied to the idealized receiver for the same element-error rate. For the purpose of this work the idealized receiver has been defined as a non-coherent detector whose element-error-rate p_e is given by:

$$p_e = \frac{1}{2} - \frac{1}{2} \operatorname{erf} (N/2)^{\frac{1}{2}}$$

where N is the normalized signal-to-noise ratio and $\operatorname{erf} (x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-x^2} dx$.

The extension of this work to cover noise other than thermal noise may result in the need for more parameters to describe fully system performance, but it seems clear that:

- the performance of telegraph circuits should be related to stated character error rates, and, for the engineering planning of circuits and design of equipment it is preferable to have these expressed in corresponding element error rates;
- the approach indicated in this document forms a useful starting point in the development of an objective method determining the performance of telegraph systems.

* This Report was adopted by correspondence without reservations (see page 9).

Instead of the “normalized signal-to-noise ratio” another quantity the “system-performance factor [3]” is sometimes used. It is equal to the number of words per minute divided by the ratio between signal power and noise power in 1 kc/s bandwidth. For a 5-element synchronous system and random arrival of errors the following relation would hold:

$$\text{System performance factor (S.P.F.)} = 27 - R_n$$

where $R_n = 10 \log_{10} N$ and the system performance factor is expressed in db. For other systems the constant will in general be different, but it can easily be calculated.

Performance curves have been calculated for an idealized non-coherent receiver and compared with those for HF telegraph receivers of modern design. The calculations apply to signals subject to Rayleigh fading and noise having a Gaussian distribution. These curves are similar and only differ by a constant factor indicating the extent by which the practical receiver falls short of the ideal. A description of equipment for measuring the demodulation factor of receivers is given elsewhere [2]. Alternatively, a measure of the demodulation factor may be obtained as in the Annex.

The basic curves for such an idealized receiver showing signal-to-noise ratio (normalized) as a function of element error rate for single, double, triple and quadruple diversity systems are given in Fig. 1. The outputs of the diversity branches are assumed to be weighted according to the signal energy and combined instead of the largest output being selected. The equations of the curves are given by:—

$$p_{e_1} = \frac{1}{2} - \frac{1}{2} \left\{ N/(N+2) \right\}^{\frac{1}{2}}$$

for Rayleigh fading and one receiver.

$$P_{e_2} = \frac{1}{2} - \frac{1}{2} \left\{ N^{\frac{1}{2}} (N+3)/(N+2)^{3/2} \right\} \quad \text{for dual diversity;}$$

$$P_{e_3} = \frac{1}{2} - \frac{1}{2} \left\{ N^{\frac{1}{2}} (N^2 + 5N + 5.3/2)/(N+2)^{5/2} \right\} \quad \text{for triple diversity;}$$

$$P_{e_4} = \frac{1}{2} - \frac{1}{2} \left\{ N^{\frac{1}{2}} [N^3 + 7N^2 + (7.5/2)N + (7.5 \cdot 3/3!)]/(N+2)^{7/2} \right\} \quad \text{for quadruple diversity;}$$

For large values of N these equations are closely approximated by:

$$p_{e_1} = 1/(2N); \quad p_{e_2} = 3/(4N^2); \quad p_{e_3} = 5/(4N^3); \quad p_{e_4} = 35/(16N^4) \quad \text{respectively;}$$

The performance of a circuit is usually expressed in terms of character-error rates. Calculations from the probability functions involved give a simple conversion from an element-error rate to a character-error rate for various types of telegraph code thus providing a simple relationship between the signal-to-noise ratio and the number of errors on the printed copy when the signal is steady. The conversion from an element-error rate to a character-error rate is more complex with fading. The particular case for random arrival of element errors represents a useful limiting condition which is approached closely when the error rate is low.

Relationships between element-and character-error rates are shown in Fig. 2 and 3.

In Fig. 2, curve (1) represents the upper limit of the character-error rate for a synchronous seven-unit code when the element errors are mutually independent. It should be noted here that the character-error rate is defined as being the number of characters subject to error at the output of the detector and thus an error in a shift character is counted only once and similarly for other characters such as carriage return and line feed. However, if the fading characteristic-give rise to groups of errors then the curve showing the relationship between element and characters error rates becomes asymptotic to curve (2) which was calculated on the assumption that the signal levels remain constant during a character. For element-error rates lower than 10^{-3} the curve (1) is appropriate.

In Fig. 3, the upper limits are shown as follows:

Curve (1) — for a five-unit synchronous code; $P_c \approx 5p_e$

Curve (2) — for a seven-unit code; $P_c \approx 7p_e$

Curve (3) — for a five-unit start-stop system with tape printing and allowing for errors due to loss of synchronism in addition to the simple character-errors; $P_c \approx 17p_e$

Curve (4) — for a five-unit start-stop system with page printing, i.e. including an additional allowance for multiple errors due to carriage return and line-feed failures. Again, as for the previous curves, errors in shift signals are only counted once. $P_c \approx 34p_e$

An example is given below to demonstrate the way in which the curves may be used. It is again stressed that these examples show the method employed in making one of the steps in the calculations necessary to plan circuits for a specified grade of service. The demodulation factor of the receiver must be known as a result of measurement.

Thus in the general case:

Let R = the pre-detection signal-to-noise ratio, (db)

R_n = the normalized signal-to-noise ratio, corresponding to R , (db), ($R = 10 \log_{10} N$)

S = the signalling speed in bauds (elements/sec.)

B = the pre-detection bandwidth (c/s) of the receiver in question

$D(S, B)$ = the demodulation factor of the receiver in question for the signalling speed and the bandwidth specified.

Then: $R = R_n + 10 \log_{10} (S/B) + D(S, B)$ (1)

Example.

A receiver having a pre-detection bandwidth of 1000 c/s is used for 50 bauds, 5-unit synchronous working, using triple diversity. The measured demodulation factor of the receiver for this signalling speed and bandwidth is 10 db. A character-error rate of 10^{-4} is permissible; what must be the pre-detector signal-to-noise ratio?

From Fig. 3 the corresponding element-error rate is 2×10^{-5} . From Fig. 1, an ideal receiver using triple diversity produces an element error rate of 2×10^{-5} for a value of $R_n = 16$ db.

Using Equation (1)

$$R = R_n + 10 \log_{10} (S/B) + D(S, B)$$

and inserting the known values we have

$$R = 16 - 13 + 10 = 13 \text{ db}$$

BIBLIOGRAPHY

1. LAW, H. B. Papers Nos. 2103 R and 2104 R. *Proc. I.E.E.*, **104**, Part B., (March, 1957).
2. LAW, H. B. *et al.* Papers Nos. 2150 R and 2259 R. *Proc. I.E.E.*, **104**, Part B., (March 1957).
3. WATT, A. D. *et al.* *Proc. I.R.E.*, (December 1958).

ANNEX

When a fading simulator is available the demodulation factor under fading conditions can be readily determined from a comparison of the measured element error-rate with the theoretical element error-rate. However, in the absence of such a fading simulator it is possible to derive an approximate value of the element error-rate under fading conditions from the results of tests under steady state conditions. These steady state tests will give the element error-rate as a distribution function $g(N)$ of the normalized signal-to-noise ratio, N .

If this function $g(N)$ can be expressed in the following form:

$$g(N) = \frac{1}{2} - \frac{1}{2} \operatorname{erf} \left(bN/2 \right)^{\frac{1}{2}}$$

which is identical with the element error-rate for an ideal receiver with a normalized signal-to-noise ratio of bN (where b is a simple numerical factor), then the demodulation factor under steady state conditions will be independent of the error-rate and will in fact be equal to $10 \log_{10} b$, db. In this case the demodulation factor under fading conditions is the same as for steady state conditions and is also independent of the order of diversity employed.

In practice, this will not generally be the case and the demodulation factor will be a function of both N and q (the order of diversity). However, by an extension of the work in Ref. [1] it can be shown that, in general, the element error-rate with q diversity branches will be:

$$p_e = \left\{ (q-1)! N^q \right\}^{-1} \int_0^\infty y^{(q-1)} \exp(-y/N) \cdot g(y) \cdot dy.$$

For the case of large signal-to-noise ratios, or small error-rates, the following approximation for the demodulation factor D_q , with q diversity branches, can be found:

$$(D_q)^q = \left\{ 2^q \cdot q! / (2q-1)! \right\} \int_0^\infty y^{(q-1)} \cdot g(y) \cdot dy$$

Measured distribution functions under steady state conditions can be expressed in the following form:

$$g(N) = \sum a_k \cdot \exp(-b_k N)$$

then for large values of N :

$$(D_q)^q = \left\{ 2^q \cdot q! \cdot (q-1)! / (2q-1)! \right\} \sum (a/b^q) \dots$$

For other forms of the function $g(N)$ similar calculations can be performed.

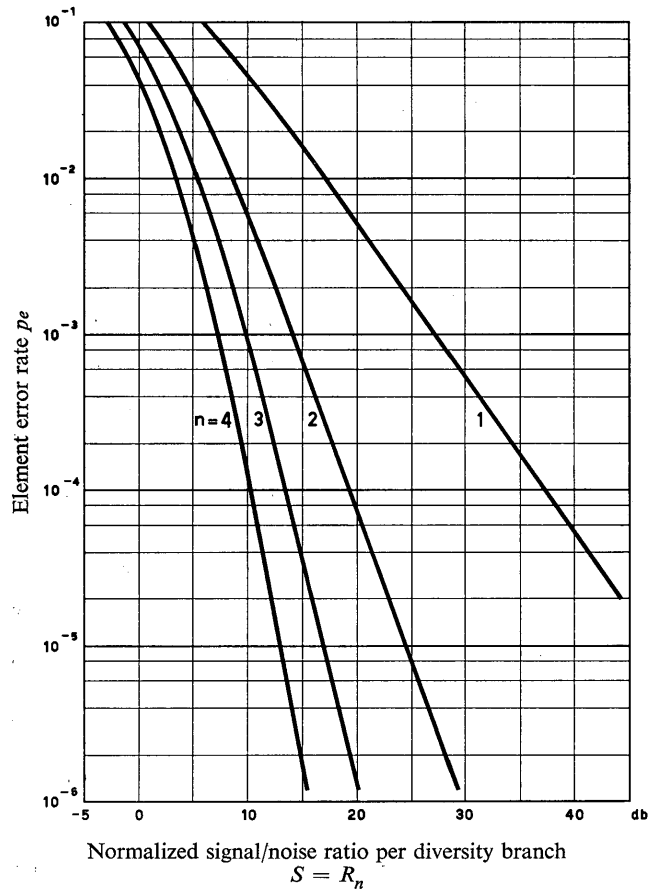


FIGURE 1

(n = the number of diversity branches).

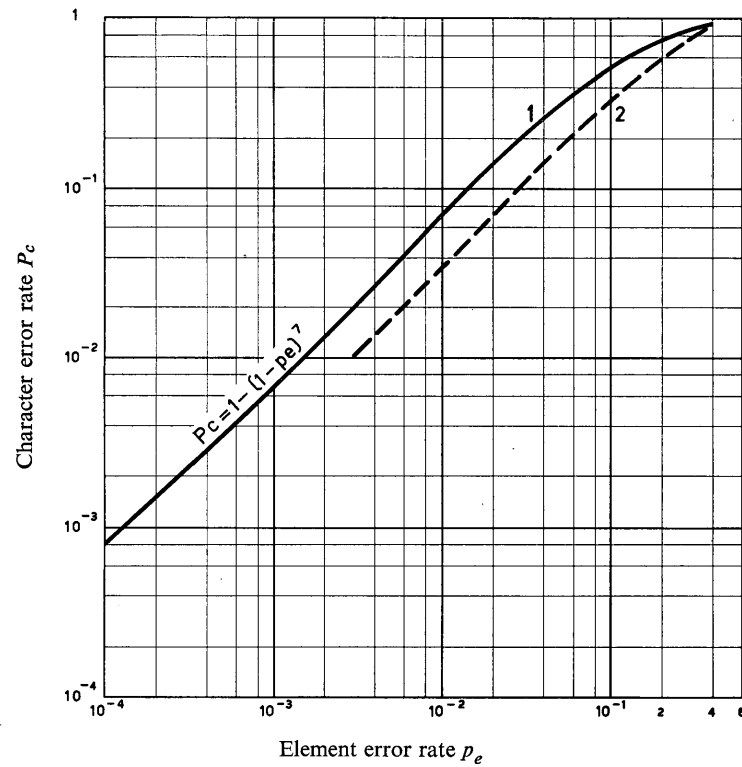


FIGURE 2



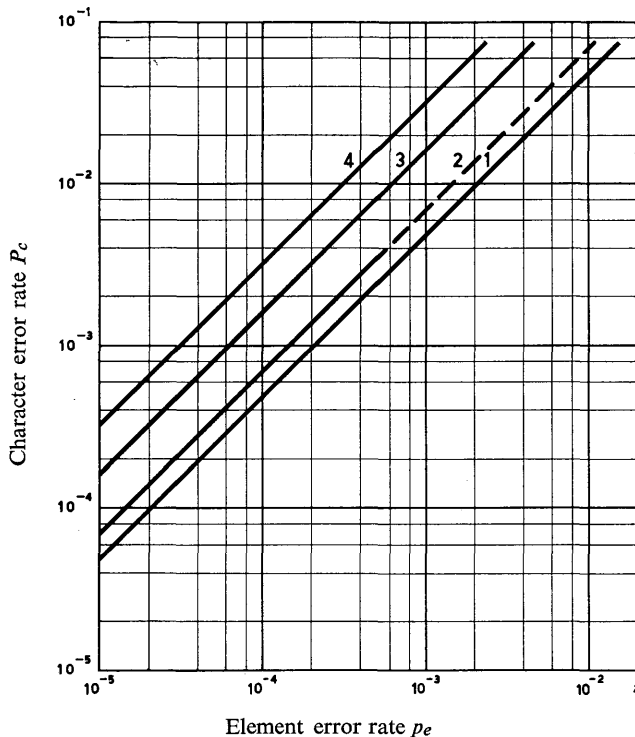


FIGURE 3

REPORT No. 106 *

IMPROVEMENT OBTAINABLE FROM THE USE OF DIRECTIONAL ANTENNAE

(Question No. 81 (III), Study Programme No. 130 (III) and Recommendation No. 162)

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

Introduction.

Contributions by administrations to the Warsaw Plenary Assembly and to the interim meeting of Study Group III at Geneva, 1958, provide a basis for a preliminary report on the question of signal power gain, and signal-to-interference discrimination, afforded in practice by rhombic antennae. The experimental observations given by Docs. III/4 and III/31 of Geneva, 1958, are summarized as well as the pertinent Docs. Nos. 19, 139, 265, 320 and 532 of Warsaw, 1956. The relation of these preliminary results to the median gain given by Recommendation No. 162 is indicated.

In the text below:

- l = length of leg (metres).
- φ = half the obtuse angle (degrees).
- h = height above ground (metres).

* This Report was adopted correspondence without reservations. (See page 9)

Summary and discussion of reported results.

Doc. III/4 (Federal German Republic) of Geneva, 1958, contains a summary (Table I below) of median values of measurements made, using a rhombic of a type in general service in the Post Administration, having $l = 115$ m, $h = 20$ m, $\varphi = 75^\circ$. This first set of measurements was made relative to a *vertical antenna*; the results are otherwise expressed in the form of the Annex to Recommendation No. 162:

TABLE I

Frequency (Mc/s)	Median value of gain relative to main lobe (direction of optimum gain) (db)				Azimuthal ranges (degrees)		
	main lobe	In Arc A	In Arc B		Half of main arc	Arc $A_1 = A_2$	Half of Arc B
			Unidirectional antenna	Reversible antenna			
10	0	—8	—21	—12	23	22	135
15	0	—6		—17	18	29	133
20	0	—8	—23	—15	13	24	143

In Document No. III/31 of Geneva, 1958, there are also reported the results of observations of the gain of the rhombic antenna in the main lobe, relative to a half-wave horizontal antenna. Mainly these observations were made at 15 Mc/s receiving WWV which transmits with an omnidirectional antenna, but there is also one set of observations made at 18 Mc/s receiving PPZ which transmits with a directional antenna. The data show the realized gain to be less than the plain-wave gain in direction of maximum response, and to have a striking variability with time of day and/or signal strength. The data are not adequate to establish a systematic diurnal variation, but the 15 Mc/s data suggest that the greatest values of gain are realized at times of high signal intensity. This result is contradicted by the observations at 18 Mc/s of transmissions from a distant directional antenna, which emphasizes the need for additional observations and draws attention to the virtually certain dependence of all such observations on the *directivity of antennae at both ends of the path*. Table II below gives the decile and median values of the gain realized in these tests.

TABLE II

Period	Gain 10% (db)	Gain 50% (db)	Gain 90% (db)
<i>Receiving WWV 15 Mc/s</i>			
11–22 June 1956 130	12.9	9.1	6.7
28 July–6 August 1956 117	15.2	11.7	7.7
29 Sep.–11 Oct. 1956 217	12.9	10.7	6.8
28 Feb.–23 Mar. 1957 405	10.8	7.1	0.0
15–25 January 1958 162	11.1	8.5	3.2
<i>Receiving PPZ 18 Mc/s</i>			
29 Sep.–10 Oct. 1956	13.0	7.8	4.4

Doc. No. 139 (United Kingdom) of Warsaw, 1956, gives results of the power gain and discrimination of rhombic receiving antennae, that is, off-azimuth response relative to maximum response. The measurements were made receiving distant transmissions at 13 and 20 Mc/s, using a ring of

30 antennae having $l = 81$ m, $h = 23$ m, $\varphi = 70^\circ$. The results are given in Table III for the main lobe and the forward arc (180°) excluding the main lobe, and for the backward arc.

TABLE III

Frequency	Main Lobe Gain (db)	Gain relative to half-wave horizontal dipole * (db)					
		Forward arc (180°) excluding main lobe			Backward arc (180°)		
		Gain 10%	Gain 50%	Gain 90%	Gain 10%	Gain 50%	Gain 90%
13.4 Mc/s (New York)	11	-2.5	-11	-19.5	-8.3	-12.7	-17
20.4 Mc/s (Pretoria)	15	+3.5	-5.0	-13.5	-4.3	-8.7	-13
20.4 Mc/s (Pretoria)	15	+2.5	-6.0	-14.5	-9.2	-13.6	-18

* Median and decile values, are relative to the arc except for the main lobe.

More detailed data are given in the same document; an examination of the data for all observed azimuths has been made, and median values of gain obtained for the arcs specified in Recommendation No. 162, as follows:

TABLE III a

Frequency	Median value * of gain relative to half-wave dipole (db)			Azimuthal range (degrees) (Rec. No. 162)		
	Main Azimuth	Arc A	Arc B	Half of main arc	Arc $A_1 = A_2$	Half of Arc B
13.4 Mc/s (New York)	11	-5	-13	12	21	147
20.4 Mc/s (Pretoria)	15	+2	-10	8½	18½	153

* Median values, are relative to the arc except for the main azimuth.

It is worth noting that values given in Table IIIa, with respect to discrimination against off-azimuth signals, are somewhat better than the values shown in Recommendation No. 162; it seems unlikely that values as favourable as given in Tables III and IIIa are generally realized in practice. The value for Arc A at 13 Mc/s is in fact better than might, at first sight, be expected; but, especially in Arc A, the available data were not adequate to establish a median value with much confidence.

In Doc. 265 (Netherlands) of Warsaw, 1956, summarized experimental observations of the power gain in the main azimuth, and for certain discrete directions off the main azimuth are given. The values of gain are for receiving rhombic antennae, expressed relative to a horizontal half wave antenna at the same height. Directional antennae were also used at the transmitters for the measurements. The design data for the receiving antennae used at Amsterdam, for which observations are summarized in this report are as follows:

Antenna	A	B
Length l (m)	120	174.5
Height h (m)	33	29.5
Angle φ (deg)	71	70
Design frequency (Mc/s)	14.5	7.5

The gain measurements for the main lobe were made on a long propagation path (7500 km), whereas some of the observations of gain off azimuth were for a medium range path (3000 km). The results gave values of realized gain which are less than expected theoretically. The data showed marked variability of gain and/or discrimination with time of day and somewhat with season though the data did not establish a systematic seasonal dependence, there was an apparent tendency for the highest values of gain in the main azimuth to be observed during periods corresponding to maximum daylight on the path; a depression of gain appeared systematically in the morning hours on the path. These data were reported for 13 Mc/s which was not worked throughout the night hours. Values of gain in directions off the main azimuth also showed marked variability with time of day and season, but the data were not conclusive as to any systematic pattern. Table IV below summarizes the observations.

TABLE IV

Antenna	Frequency (Mc/s)	Gain relative to half-wave horizontal antenna (db)									
		Main lobe				Distance (km)	Azimuth relative to main lobe (degrees)	Off-azimuth			
		Hours of obs.	Gain 10%	Gain 50%	Gain 90%			Hours of obs.	Gain 10%	Gain 50%	Gain 90%
A	7.7	83	9.4	8.3	6.7	2000	317	17	8.5	5.6	2.4
	13.7	158	13.4	11.4	8.8	3200	236	49	—7.3	—8.7	—10.3
	13.7					9300	143	56	—2.9	—10.7	—13.5
	13.7					2000	14	14	1.8	0.5	—1.4
	13.7					5800	37	42	6.1	4.5	0.2
	17.6	46	14.2	13.3	12.1						
B	7.7	30	15.0	11.4	7.6						
	13.7	50	13.7	11.0	9.2						
	17.6	34	9.9	7.8	6.0						

Doc. No. 320 (Japan) of Warsaw, 1956, concludes that discrimination of greater than 15 to 20 decibels cannot be relied upon; a number of observations are cited for values of discrimination (response outside the main lobe, relative to response in the main lobe) for a rhombic antenna having values of $l = 120$ m and $\phi = 70^\circ$ (height unspecified). These are shown in Table V below; there were not enough data available to permit statistical analysis in terms of the arcs of Recommendation No. 162.

Doc. 19 of Warsaw, 1956, draws attention to azimuthal variations of signals propagated over great distances via the ionosphere, in relation to realized directivity of antennae at great distances. Measured azimuths show only slight differences among the values of deviation for propagation paths of various lengths. 80% of the measurements showed less than $\pm 2^\circ$ average deviation; 98% showed average deviation less than $\pm 4^\circ$. The shortest link observed (2000 km) showed the greatest deviation and the longest path the least deviation.

Conclusions.

The present data do not offer an adequate basis for revision of Recommendation No. 162. The results show striking variability of gain and/or discrimination with time, especially time of day and to some extent season of the year. There are undoubtedly important effects near times

of sunrise and sunset, at times of signal failure on operating frequencies near the MUF, and at times of ionospheric disturbance when great azimuth deviations can be observed. Statistical correlation of values of gain with values of transmission loss would be of interest and the data expected from Study Programme No. 130 (III) may be expected to show whether and under what circumstances such a correlation exists. The data given above suggest the extent of azimuth deviation encountered during normal propagation conditions. It must be noted that because of the influence of irregularities in the ionosphere, such as give rise to azimuth-deviations, the directivity gain realized at the receiving terminal depends in a fundamental way on the directivity of the transmitting antenna—and vice-versa. It is, therefore, important in carrying out observations (such as those outlined in Study Programme No. 130 (III) to specify the directivity of antennae at both terminals.

TABLE V

Median Values of Discrimination in Decibels
(Off Azimuth Response Relative to Main Lobe)

Difference in Azimuth (degrees)	Frequency Ranges (Mc/s)					
	10.3 to 12.2		13.3 to 14.5		14.5 to 15.6	
	Median	Median Standard Deviation	Median	Median Standard Deviation	Median	Median Standard Deviation
6					3.8	2.1
12½			12.5	2.0	8.9	2.5
18½					8.0	3.2
21					9.8	1.4
22			7.5	2.9		
25½	9.3	1.4				
27					13.5	1.7
39½					12.5	2.1
46½					14.5	1.4
52½					17.6	2.0
79½			19.8	2.8		
93			12.5	3.6		
109½			20.3	3.8		
117	15.5	2.1				
168½			11.8	3.4		

REPORT No. 107 *

DIRECTIVITY OF ANTENNAE AT GREAT DISTANCES

(Recommendation No. 102)

(Los Angeles, 1959)

Methods of testing the directivity of antennae at great distances have been:

- (a) "Statistical method", a comparison of numerous observations of the same signal on different fixed antennae at the same location but at different orientations. [1, 2 and 3]
- (b) Mechanical rotation of antenna structures with various approaches to data statistics. [4 and 5]
- (c) Backscatter method, a comparison of backscatter signals in a method similar to that of (a) above. [6]

Most of the studies have been made at high frequencies, although at least one was performed in the standard M.F. broadcast band [7].

References [4] and [5] indicate that at moderately long distances the main lobes are on the average preserved, even under conditions of severe ionospheric disturbance. A more serious matter, which merits further study, is the question of preservation of nulls and front-to-back ratios. Reference [7] indicates that these are not preserved at medium frequencies. Measurements of these effects are very difficult because of noise and interference. Besides, electrical balance at both polarizations in antennae, feeders, and equipment antenna circuits is a very critical matter in the realization of nulls and minima with rhombic antennae in ionospheric propagation [8].

References [9] and [10] deal with non-great-circle effects. These effects were noted in the 1930's [11].

The effect of the propagation medium on transmission loss at different antenna orientations is dealt with in Reference [12].

The directivity of antennae at great distances is dealt with in the following documents:

- Question No. 81 (III) — Directivity of antennae at great distances
- Study Programme 130 (III) — Improvement obtainable from the use of directional antennae
- Recommendation 162 — The use of directional antennae
- Report No. 106, [3] — Report on Study Programme 85 outlining the results of experiments in the Federal German Republic (Docs. III/4 and III/31 of Geneva, 1958), United Kingdom (Doc. 139 of Warsaw, 1956), Netherlands (Doc. 265 of Warsaw, 1956) and Japan (Doc. 320 of Warsaw, 1956) in which the "statistical method" was used for the determination of gain in the 3 azimuthal arcs M , A , and B , specified in Recommendation No. 162. It was recognized that these gains were in some way dependent upon ionospheric conditions. It was also noted that the directivity gains were to some extent a function of the directivity of both antennae.

Note. — It is noteworthy that in the IRE Standards on transmitters, modulation systems and antennae, 1948, the definition of "directivity" is: "the value of the directive gain in the direction of the maximum value", thus differing from the usage of Recommendation No. 102.

* This Report was adopted by correspondence without reservations (see page 9).

BIBLIOGRAPHY

1. Doc. No. 23 of Geneva, 1951.
2. Doc. No. 206 of Geneva, 1951.
3. Report No. 106.
4. PESSON, Admiral G. Papers appearing in *Rassegna delle P.T.T.*, September 1935 and *Alta Frequenza*, August 1936. Work abstracted in C.C.I.R. Stockholm, 1948 book: (Proposals submitted to the C.C.I.R.), Study Group 2, (Radio Propagation), p. 288.
5. SILBERSTEIN, R. The Long-Distance Horizontal Radiation Pattern of a High-Frequency Antenna. *National Bureau of Standards Report No. 3538*. Abstract given in *Transactions of the Institute of Radio Engineers, Vol. AP-5 (Antennas and Propagation) No. 4*, 397 (October 1957).
6. BECKMANN, B. and VOGT, K. Beobachtung der Rückstreuung im Kurzwellengebiet an Kommerziellen Telegraphiesignalen (Observations on backscattering of commercial telegraph signals in the high-frequency band). *Fernmeldtechnische Zeitschrift*, Vol. VIII (1955), 473-481. Doc. VI/45 of Geneva, 1958, contains some of this material.
7. FINE, H. and DAMELIN, J. Suppressional Performance of Directional Antenna Systems in the Standard Broadcast Band. *Federal Communications Commission Report, TRR-1.2.7*.
8. BRUECKMANN, H. Suppression of Undesired Radiation of Directional HF Antennas and Associated Feed Lines. *Proc. IRE*, 46, 1510-1516, (Aug. 1958).
9. MIYA, K., ISHIKAWA, M. and KANAYA, S. On the bearing of Ionospheric Radio Waves. *Rep. Ionosphere Res. Japan*, 9, No. 3, 130-144 (1957).
10. MIYA, K. and KAWAI, M. On the Propagation of Long-Distance HF Signals above the Classical MUF, — Pulse and Dot Transmission Tests between England and Japan, to be published in *Electronic and Radio Engineer* (U.K.).
11. KEEN, R. *Wireless Direction Finding*, 4th ed. 1947, Iliffe and Co., London.
12. NORTON, K. A. System Loss in Radio Wave Propagation (See Sec. 9 of Report). *National Bureau of Standards Journal of Research*, 63 D, 1, 53-74 (July-Aug. 1959).

REPORT No. 108 *

THE USE OF AUTOMATIC ERROR CORRECTION OF TELEGRAPH SIGNALS TRANSMITTED OVER RADIO CIRCUITS

(Study Programme No. 128 (III))

(Los Angeles, 1959).

1. The studies carried out to answer Question No. 129 have given rise to Recommendation No. 242, which is not a complete answer to the question.
2. Operational experience has shown that the present Recommendation does not permit the establishment of circuits which can be so phased that incorrect routing of traffic is prevented in all circumstances (e.g. when the signal is received with unintentionally reversed polarity).
3. A method has therefore been devised which permits unambiguous phasing to be achieved. For this method to be used, a number of modifications to the existing channel arrangement are necessary.

* This Report was adopted unanimously.

4. The operation of sub-divided channels as set out in Recommendation No. 242 calls for different channel coding than that at present used for full-speed operation. The increasing use of sub-divided channels makes this practice undesirable, and a unified coding arrangement for full-speed and sub-divided channel operation is to be preferred.

5. To permit unambiguous phasing, two conditions must be met:

5.1 In each channel, one character per repetition cycle is “marked” by inversion.

5.2 The relative positions of the “marked” characters in each channel must be fixed in such a way as to provide a unique pattern for the aggregate signal.

6. The following arrangement permits unambiguous phasing in all circumstances.

The channel arrangement is as follows:

6.1 *Channel A*:

6.1.1 For 4-character repetition cycle (full-speed or sub-divided): one character keyed reversed followed by three characters keyed direct.

6.1.2 For 5-character repetition cycle (full-speed only, where a 4-character cycle is not sufficient): One character keyed reversed followed by four characters keyed direct.

6.1.3 For 8-character repetition cycle (for sub-divided operation where a 4-character repetition cycle is not sufficient): one character keyed reversed followed by seven characters keyed direct.

6.2 *Channel B*:

6.2.1 For 4-character repetition cycle (full-speed or sub-divided): one character keyed direct followed by three characters keyed reversed.

6.2.2 For 5-character repetition cycle (full-speed only, where a 4-character cycle is not sufficient): one character keyed direct followed by four characters keyed reversed.

6.2.3 For 8-character repetition cycle (for sub-divided operation where a 4-character cycle is not sufficient): one character keyed direct followed by seven characters keyed reversed.

6.3 *Channel C*:

Keyed as for Channel B.

6.4 *Channel D*:

Keyed as for Channel A.

6.5 The relative positions of “marked” characters in each channel is as follows:

6.5.1 The first direct character on A transmitted after the reversed character on A shall be followed by the direct character on B.

6.5.2 The direct character on C shall be followed by the reversed character on D.

6.5.3 The reversed character on A is element-interleaved with the direct character on C.

6.5.4 In the aggregate, A elements precede those of C, and B elements precede those of D.

7. While application of 5 or 8 - character repetition cycles is comparatively infrequent, it is important to define, at an early stage, the convention to be used, to ensure compatibility between systems.



REPORT No. 109 *

RADIO SYSTEMS EMPLOYING IONOSPHERIC SCATTER PROPAGATION

(Question No. 132 (III))

(Los Angeles, 1959)

A contribution relating to Question No. 132 (III) has been received from U.S.A. (Document No. III/29 of Geneva, 1958); references are cited in which information on ionospheric scatter propagation relevant to exploitation of systems has been published [1, 6].

1. Variation with frequency of propagation characteristics relevant to the use of systems.

For estimation of the performance of fixed systems it is important to know the variation with frequency, of the mean signal intensity, the fading characteristics, such as short term amplitude distribution and fading rate, and the background galactic noise level. For practical purposes received power may be considered inversely proportional to approximately the 7th power of frequency, using scaled antennae. The background galactic noise is inversely proportional to the 7/3 power of frequency. The resulting signal-to-noise ratio, using scaled antennae, is proportional approximately to f^{-5} . Studies have shown that the frequency dependence during hours of weakest signal intensity is not significantly different from that observed for the mean signal intensity. The short term amplitude distribution of signal intensity approximates a Rayleigh distribution at frequencies observed in the range of 30 to 74 Mc/s. The typical measured fading rate (median crossings) at 50 Mc/s is approximately 1 c/s; the fading rate is proportional to operating frequency raised to a power of 0.7 to 1.2 depending on conditions.

Another important propagation characteristic which varies with frequency is the occurrence of long distance F2 propagation giving rise to mutual interference and backscatter, which represents a source of self-interference to a scatter system used for high speed telegraph services. The occurrence of this type of propagation is dealt with in the following paragraphs, along with consideration of mutual interference

2. The extent to which systems employing this mode of propagation and operating on the same or neighbouring frequencies are liable to interfere with each other and with other services.

The propagation modes most significant in long distance interference between scatter services and other services are sporadic-E and F2. Adequate worldwide measurements of sporadic-E are not yet available to permit a complete evaluation of the percentage of time that interference is likely to occur. A comprehensive study of worldwide occurrence of E_s observed at HF by ionosphere recorders has been published [7, 8]. For practical purposes ionosphere scatter circuits, to avoid sporadic E interference, should have their transmitting and receiving terminals geographically separated from other circuits or services by at least 3000 kilometres. Fig. 1-12 represent contours of F2—4000 km MUF exceeded 1% and 10% of the hours during three seasons of the

* This Report was adopted by correspondence (see page 9). The United Kingdom reserved its opinion on this Report.

year at times of sunspot maximum and minimum. These are derived from a standard C.R.P.L. F2 prediction data, using measured distributions of day-to-day values of F2 MUF about the median. A circle of 2000 km radius centred on the station gives the locus of frequencies at which propagation over 4000 km paths occurs 1 % or 10 % of the time during the season indicated. The percentage of the time is less for paths longer or shorter than 4000 km. Figs. 1-12 inclusive may be regarded as provisional and subject to revision at such time as the C.C.I.R. may adopt appropriate data regarding F2 MUF values.

3. Radio frequency and baseband characteristics of ionosphere scatter systems.

Ionospheric scatter systems of high reliability are currently in operation and the number of such systems may be expected to increase. These systems employ highly directional antennae and transmitter output powers of the order of 40 kW.

In view of rapid technical advances, standardization is not practical at this time. Therefore, the modulation characteristics of typical systems in use or under consideration are presented for illustration:

- (a) a single voice channel of response from 300 to 3100 c/s using SSB, or NBFM with a peak deviation of 3 kc/s;
- (b) four to sixteen channel, time division multiplex, at a rate of 150 to 600 bauds with frequency shift keying; a separation of 6 kc/s is commonly used between mark and space frequencies to minimize errors due to Doppler components;
- (c) combinations of the above using linear transmitters, such as a voice channel and an FSK system or two independent FSK systems; as an alternative, two transmitters may be used, with one carrying voice intelligence and the other teleprinter;
- (d) a system has been proposed with a single voice channel and four channels of teleprinter, using error correction and detection techniques at 177 bauds. A typical assignment for 20 kc/s spectrum occupancy is shown in Fig. 13.

Modulation characteristics of the propagation medium must be considered in system application. Some pertinent characteristics are:

- (a) diversity reception is beneficial for voice or teleprinter operation and dual or triple diversity is commonly used;
- (b) the coherence bandwidth as determined by multipath considerations of the transmission medium is limited to approximately 3 kc/s;
- (c) meteoric multipath will, in general, provide the limitation on the maximum baud rate;
- (d) during periods where the MUF may be above the operating frequency, F2 propagation may be expected. The above conditions are frequently accompanied by long-delay multipath echoes, ranging up to 50 ms or more. The echo pulses may have amplitudes comparable to or even greater than the desired signal, thus resulting in a very high error rate. Long-delay multipath problems may find solution by the use of antennae having more desirable



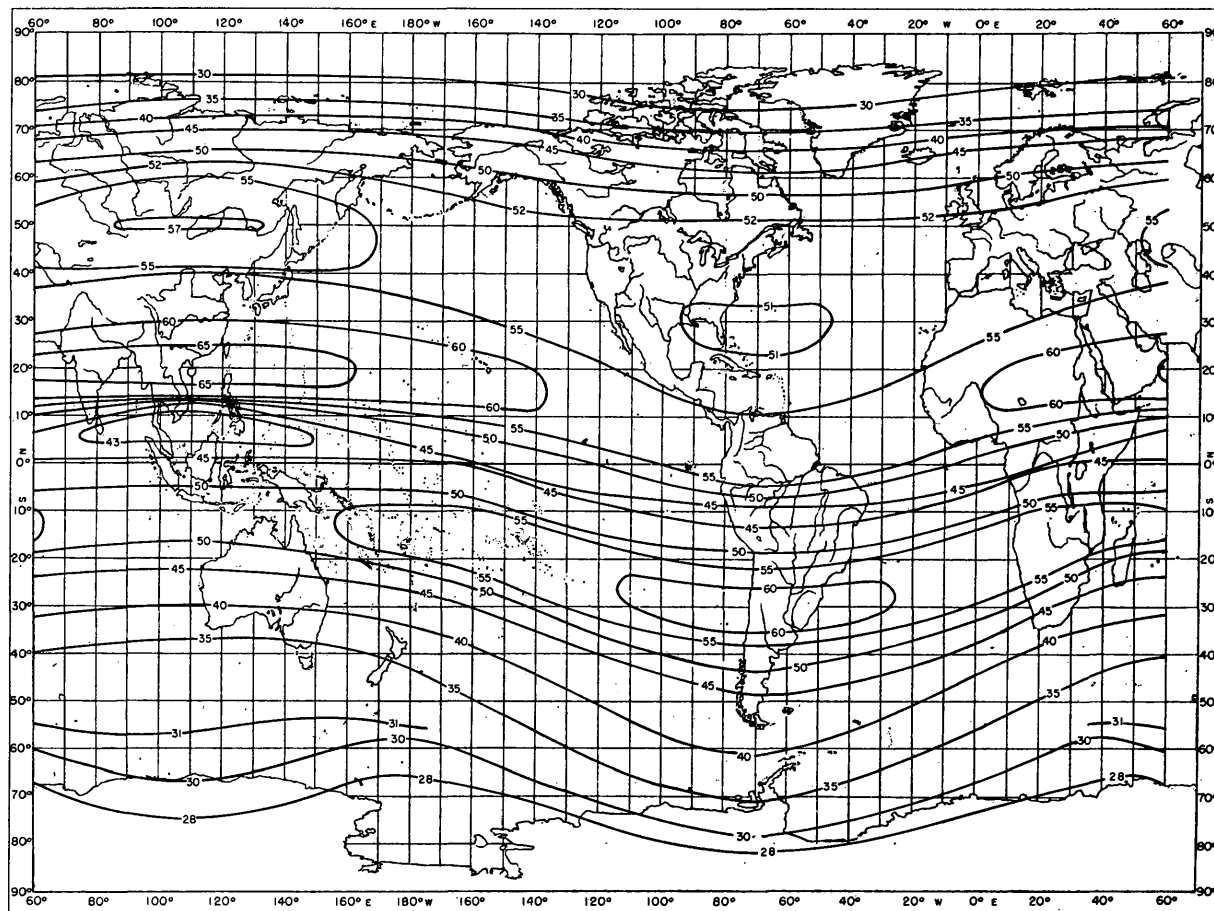


FIGURE 1

Values of the F2 4000 MUF exceeded for 1% of hours ; December solstice, sunspot maximum

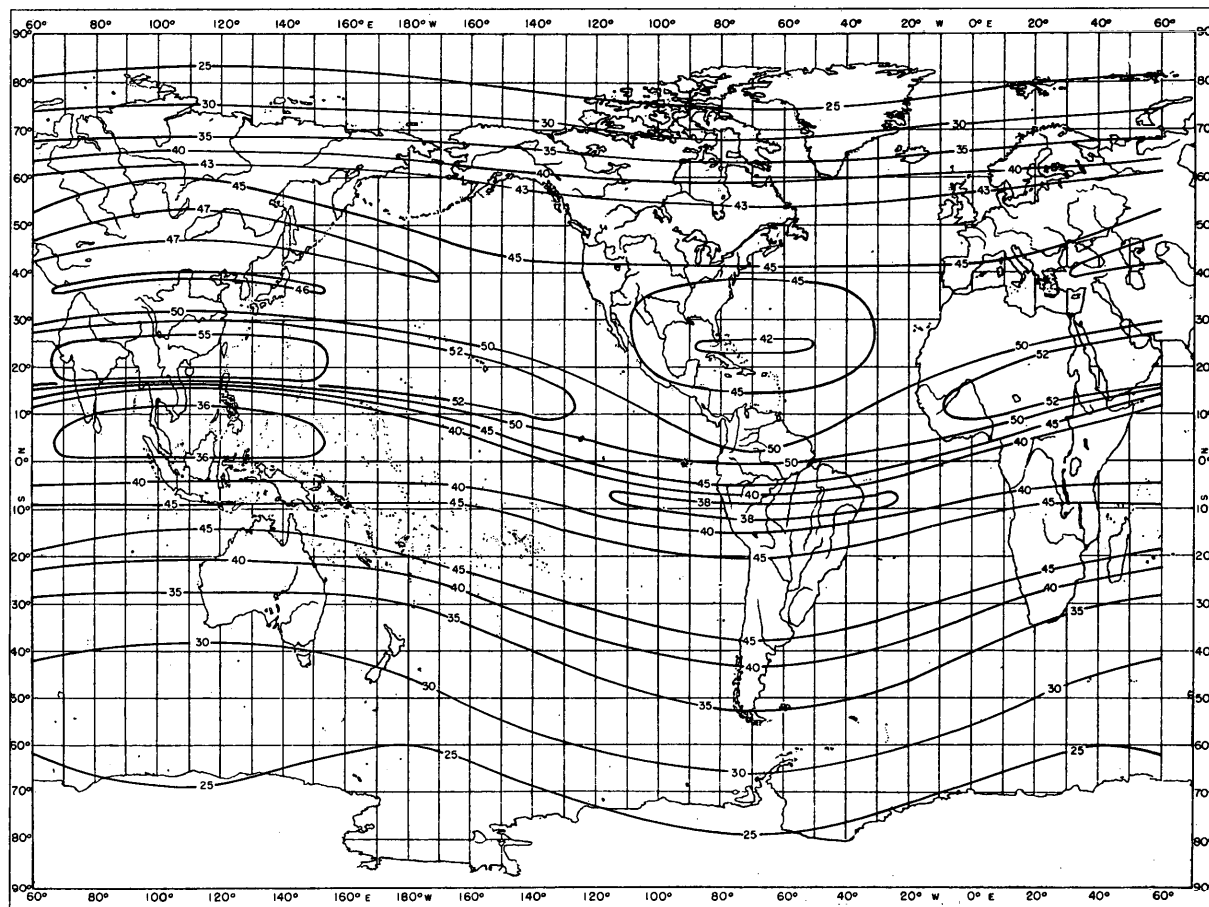


FIGURE 2
Values of the F2 4000 MUF exceeded for 10% of hours ; December solstice, sunspot maximum



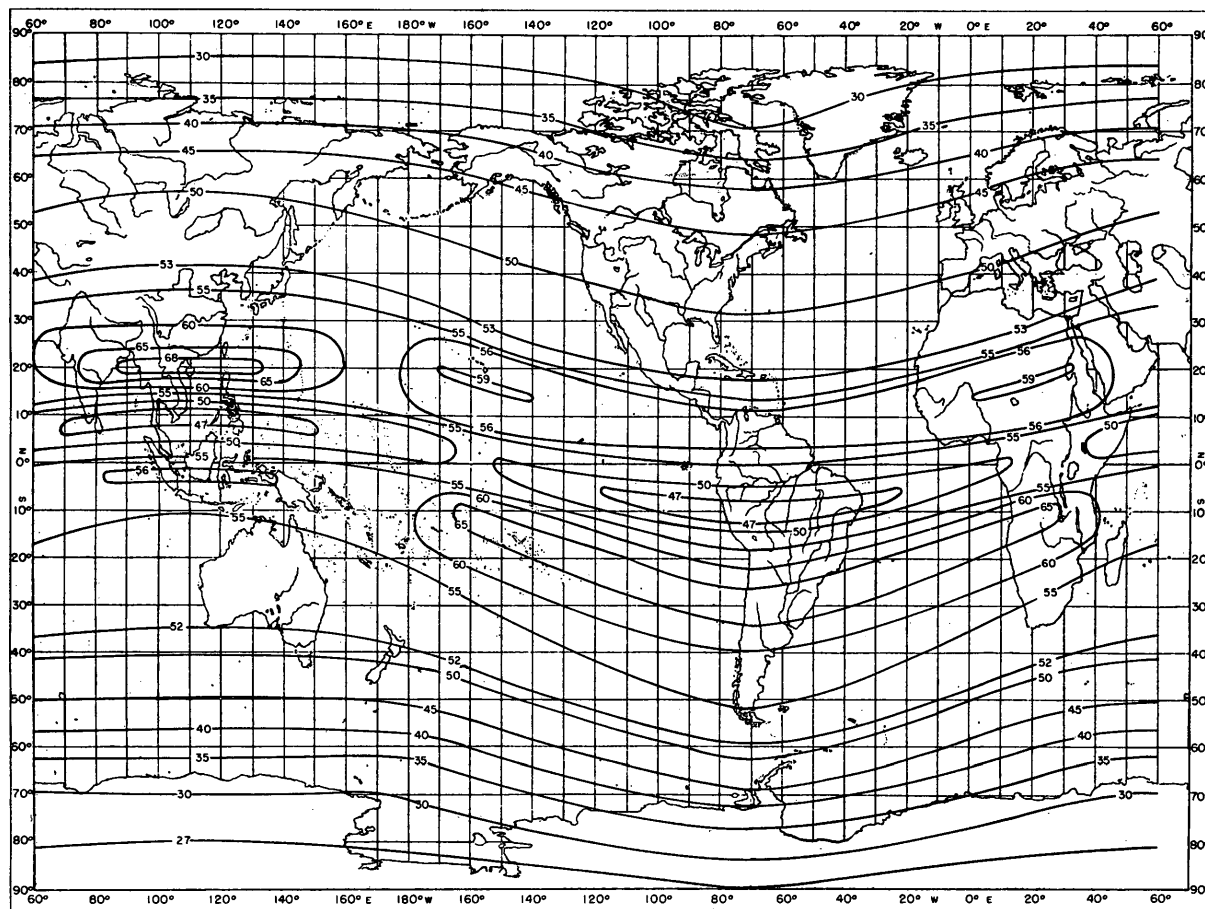


FIGURE 3
 Values of the F2 4000 MUF exceeded for 1% of hours ; Equinox, sunspot maximum

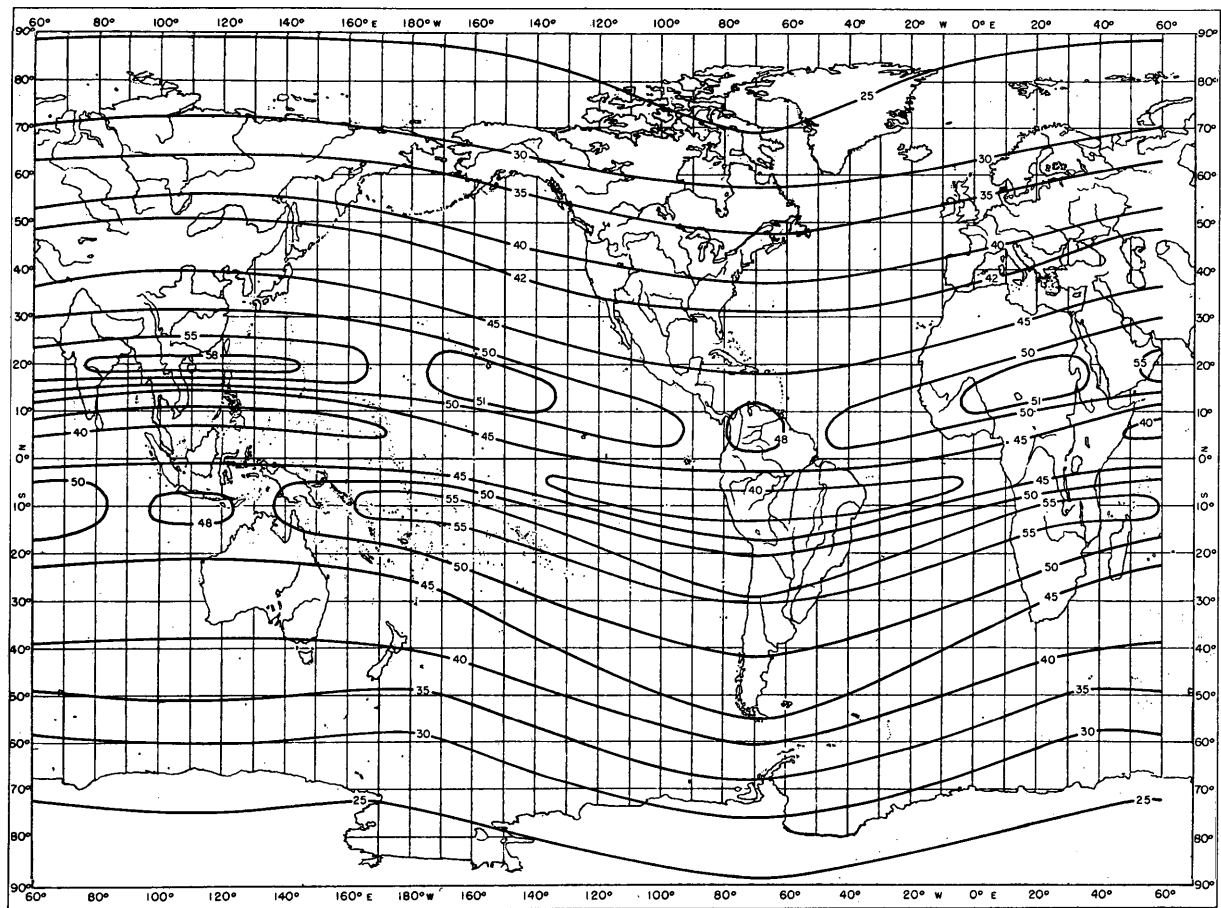


FIGURE 4

Values of the F2 4000 MUF exceeded for 10% of hours ; Equinox, sunspot maximum



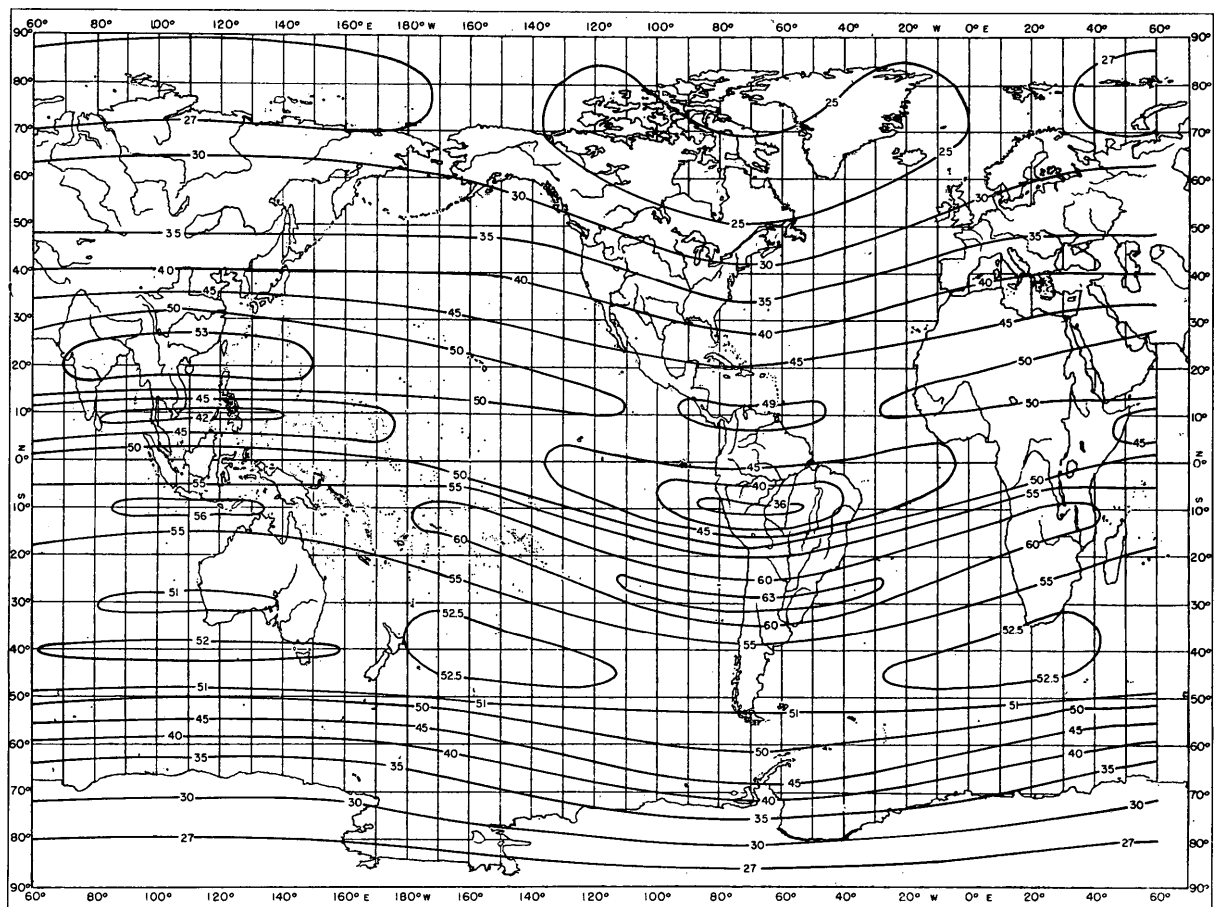


FIGURE 5

Values of the F2 4000 MUF exceeded for 1% of hours ; June solstice, sunspot maximum

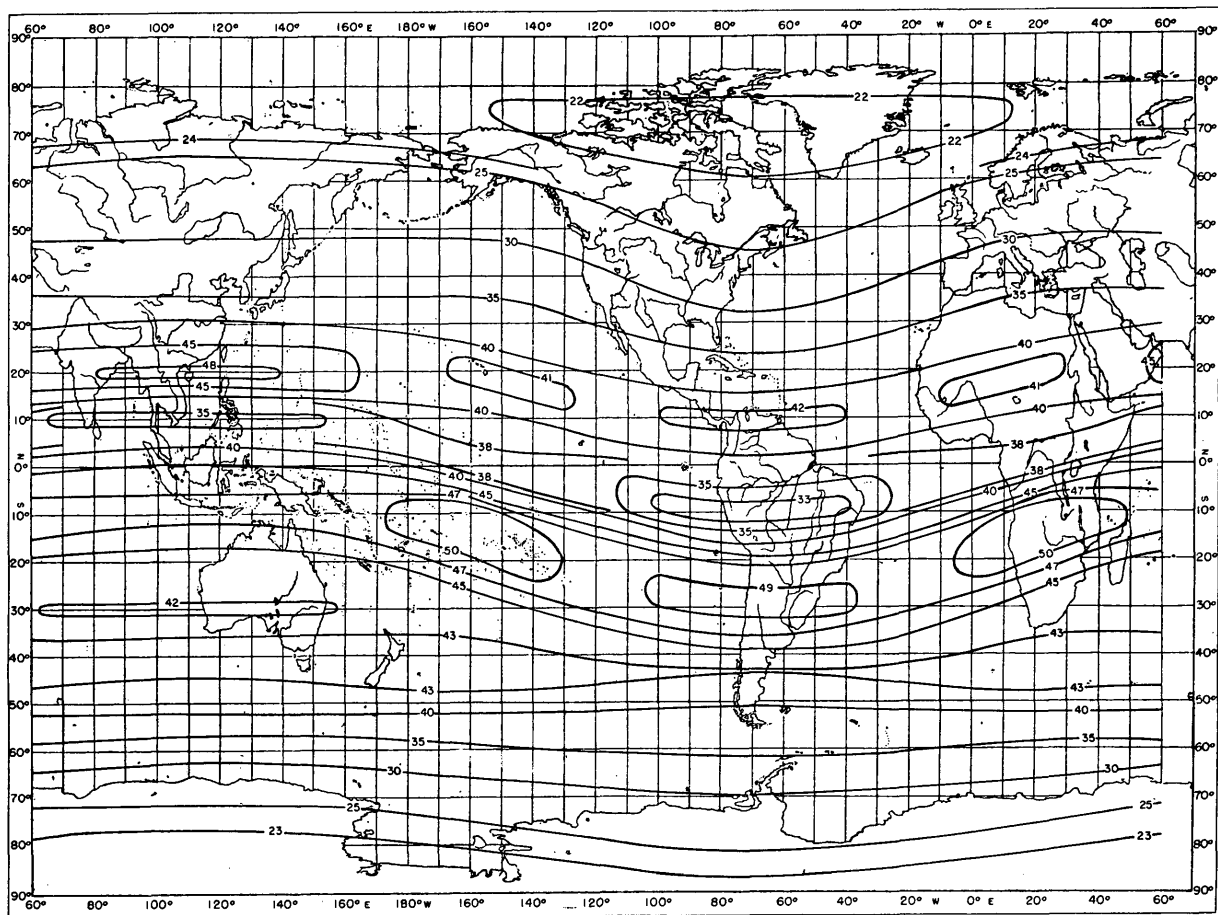


FIGURE 6
Values of the F2 4000 MUF exceeded for 10% of hours ; June solstice, sunspot maximum



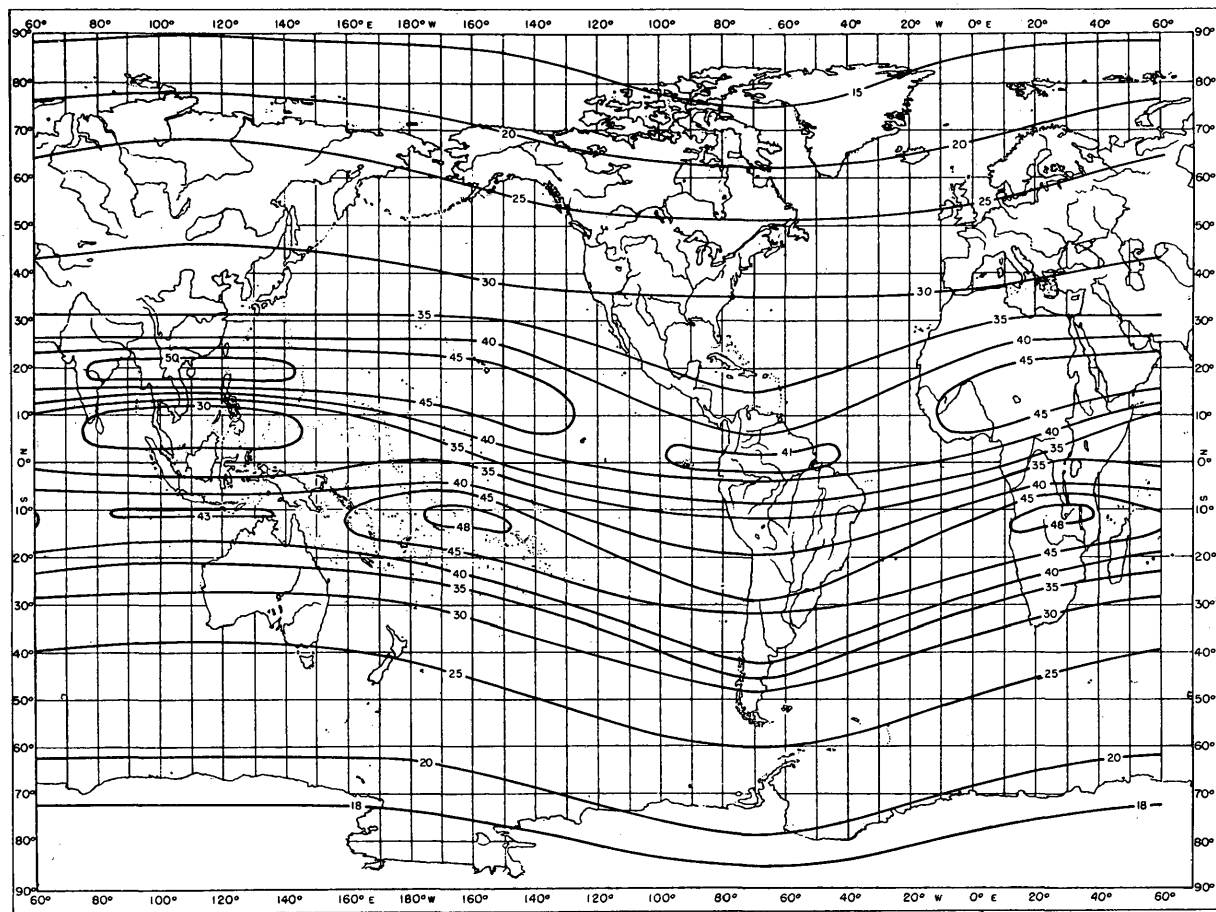


FIGURE 7

Values of the F2 4000 MUF exceeded for 1% of hours ; December solstice, sunspot minimum

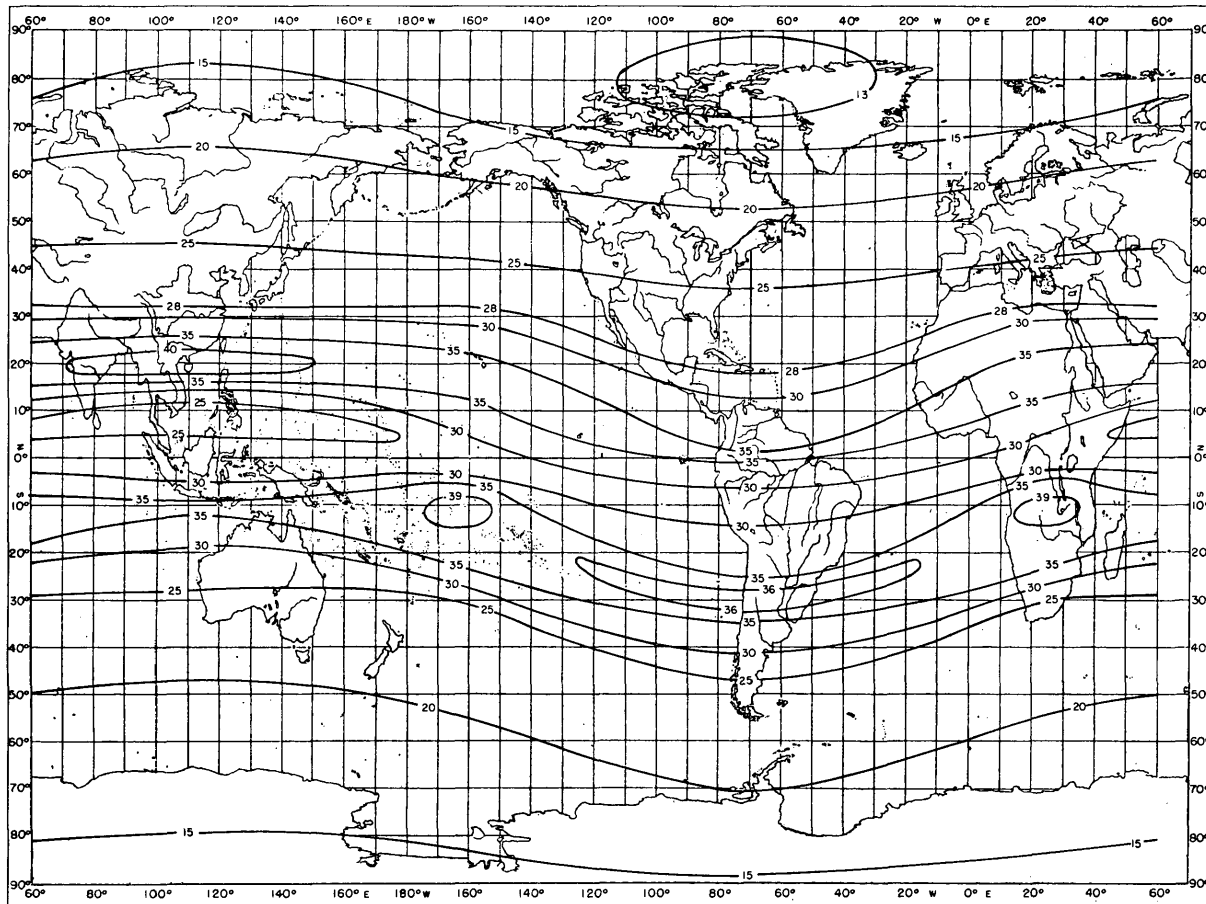


FIGURE 8

Values of the F2 4000 MUF exceeded for 10% of hours ; December solstice, sunspot minimum



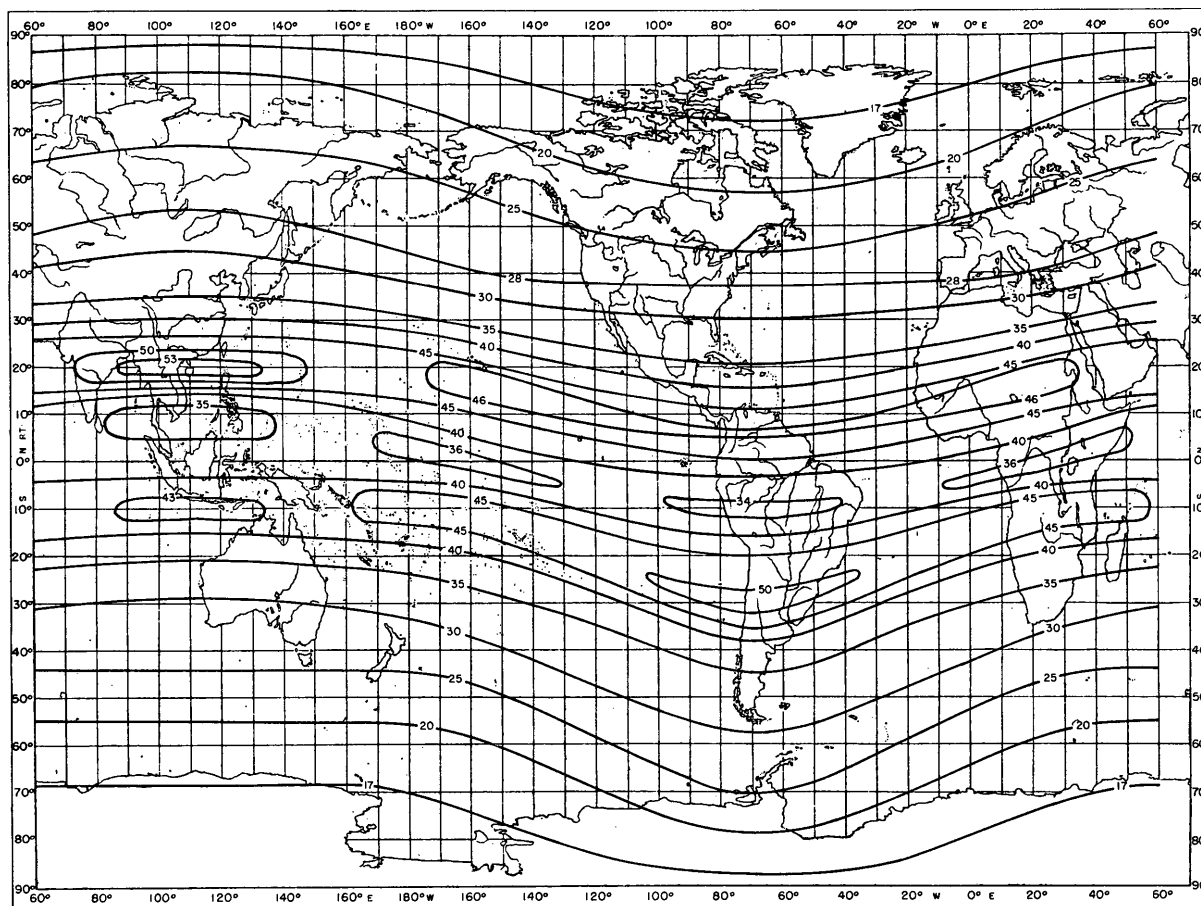


FIGURE 9

Values of the F2 4000 MUF exceeded for 1% of hours ; Equinox, sunspot minimum

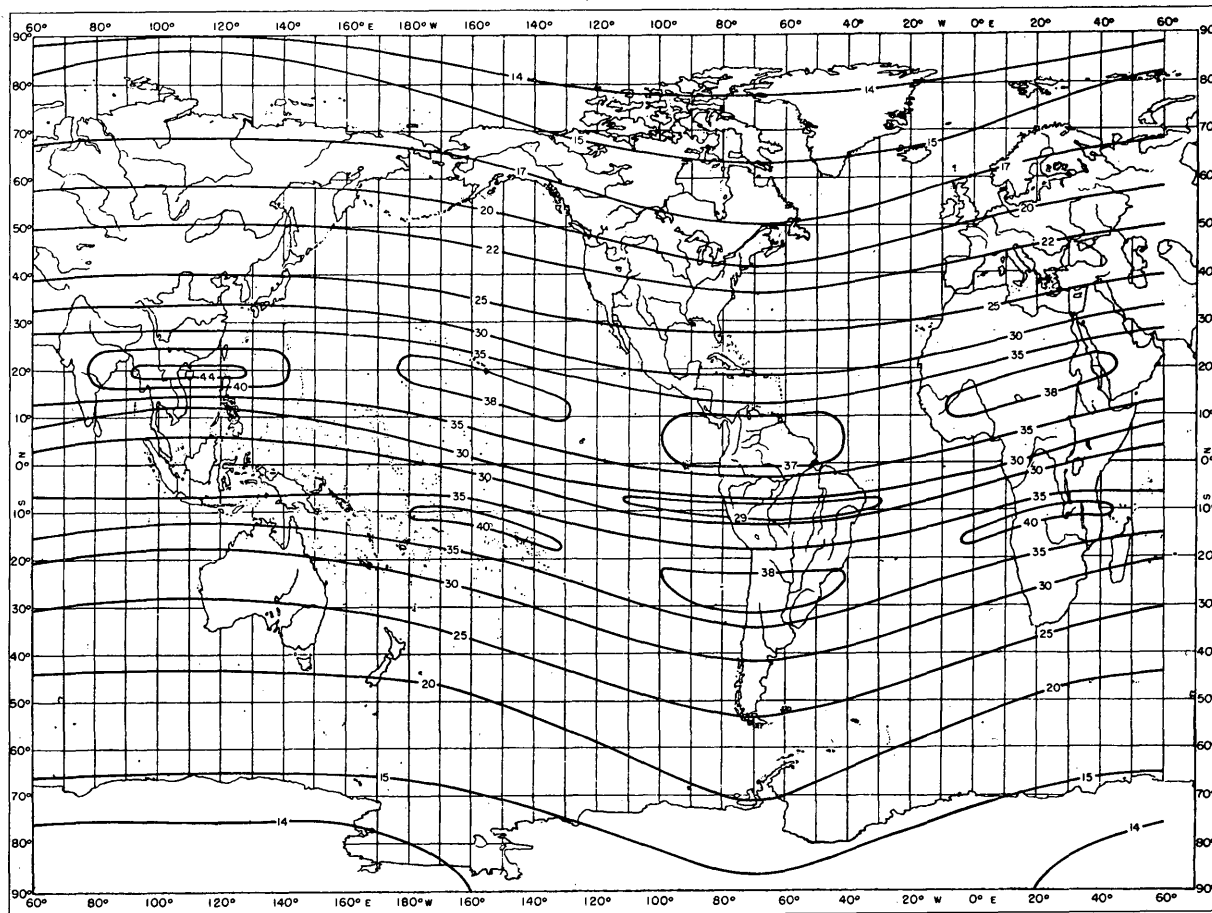


FIGURE 10
Values of the F2 4000 MUF exceeded for 10% of hours ; Equinox, sunspot minimum



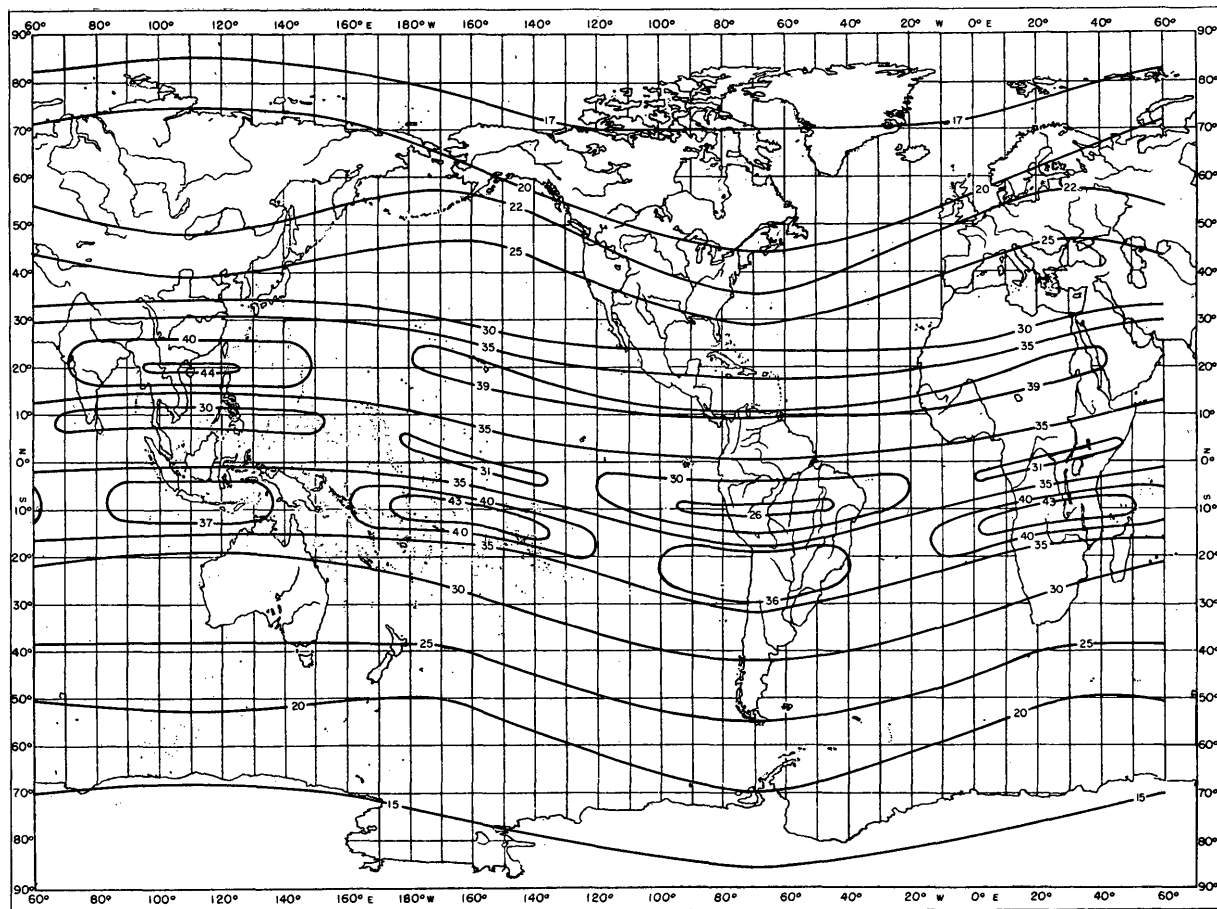


FIGURE 11

Values of the F2 4000 MUF exceeded for 1% of hours ; June solstice, sunspot minimum

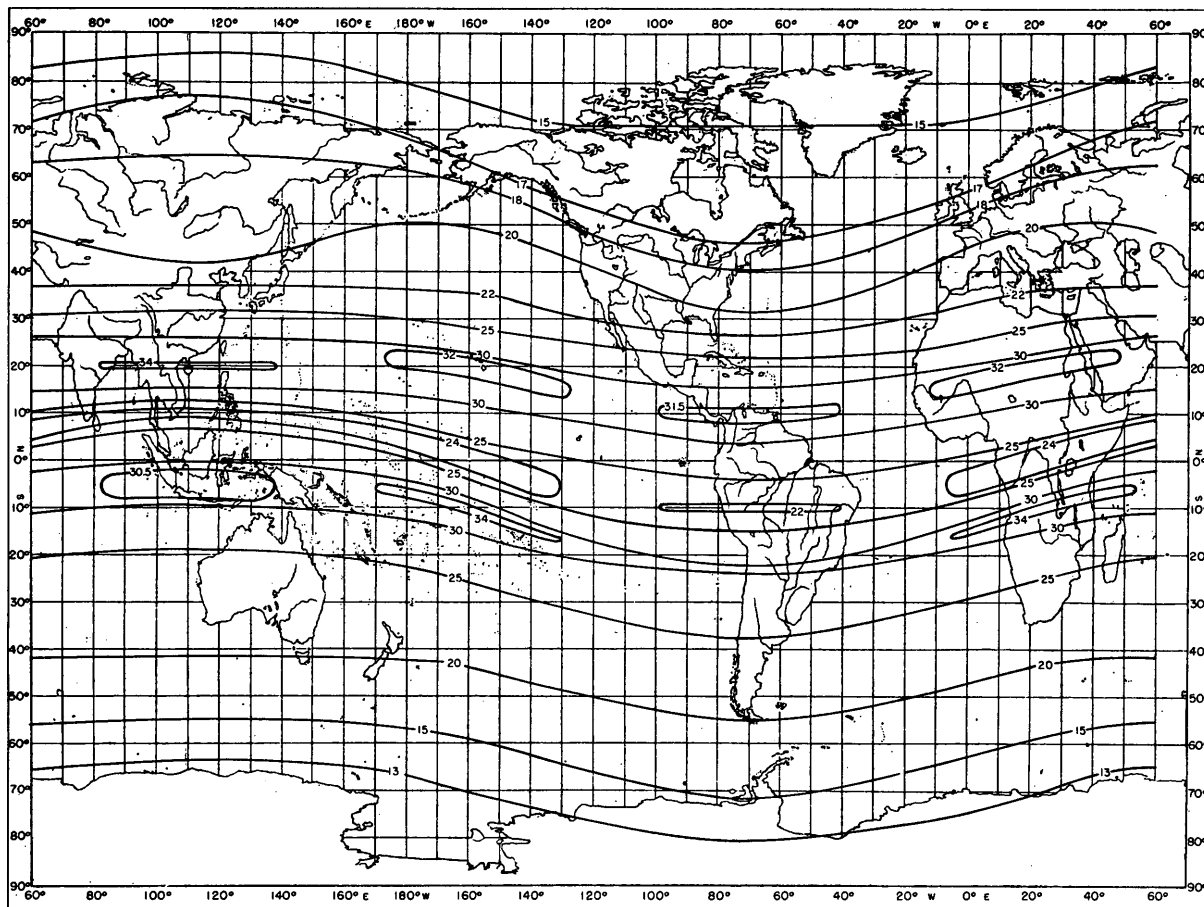


FIGURE 12
Values of the F2 4000 MUF exceeded for 10% of hours ; June solstice, sunspot minimum



directivity characteristics, the use of a frequency above MUF, or by the use of special modulation techniques;

- (e) ionospheric scatter systems characteristically employ high power and highly directional antennas; during periods of sporadic E or high MUF, they must be considered as potential sources of interference to other services sharing the same frequency band;
- (f) current four-channel teleprinter systems using dual space diversity typically require a signal-to-noise ratio of 24 db (noise measured in a 250 c/s band) for a binary error rate of 1×10^{-4} ;
- (g) voice systems currently in use will provide usable operator-to-operator quality over a single link with an RF signal-to-noise ratio of approximately 14 db, as measured in a 3 kc/s noise bandwidth.

The frequencies used for this mode of propagation are generally between 30 and 40 Mc/s. A few circuits currently being installed will use dual frequency operation. Higher frequencies, perhaps as high as 60 Mc/s, will be useful as a means to avoid distance propagation during periods of high F2 MUF's at time of maximum solar activity.

The distances over which these circuits operate generally range from 1000 to 2000 kilometres, and several of these circuits are now in operation in arctic regions.

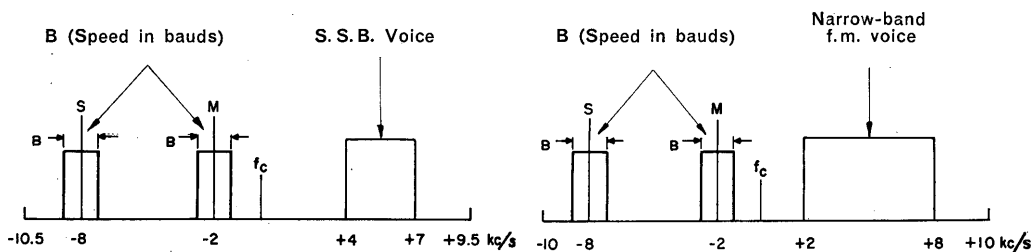


FIGURE 13

Typical 20 kc/s spectrum assignments for ionospheric scatter transmission
(B is the frequency in c/s corresponding to the telegraph speed in bauds)

BIBLIOGRAPHY

1. BAILEY, D. K., BATEMAN, R. and KIRBY, R. C. Radio Transmission at VHF by Scattering and Other Processes in the Lower Ionosphere. *Proc. I.R.E.*, **43**, 1181-1230, (1955).
 2. ABEL, W. G., DE BETTENCOURT, J. T., CHISHOLM, J. H. and ROCHE, J. F. Investigations of Scattering and Multipath Properties of Ionospheric Propagation at Radio Frequencies Exceeding the MUF. *Proc. I.R.E.*, **43**, 1255-1268, (1955).
 3. BRAY, W. J., SAXTON, J. A. WHITE, R. W. and LUSCOMBE G. W., VHF Propagation by Ionospheric Scattering and its Application to Long-Distance Communication. *Proc. I.E.E.*, **103**, Part B, 236-260, (1956).
- In addition to the above, attention is drawn to entire issues of journals as follows:
4. *Proc. I.R.E.*, **43**, 10, (October 1955).
 5. *I.R.E. Transactions on Communications Systems*, Vol. CS-4, 1, (March, 1956).
 6. I.E.E. Symposium on Long-Distance Propagation above 30 Mc/s, London, (January 28, 1958). Papers to be published in Vol. 105, Part B, *Journal of the I.E.E.*
 7. SMITH, E. K. Worldwide Occurrence of Sporadic E. *National Bureau of Standards Circular 582*, (March 15, 1957).
 8. SMITH, E. K. and DAVIS, R. M., Jr. The Effect of Sporadic E on VHF Transmission in the U.S., in publication.

REPORT No. 110 *

THE RELATION BETWEEN PERMISSIBLE DELAY AND RESIDUAL
UNCERTAINTY AND ITS DEPENDENCE ON BANDWIDTH UTILIZATION

(Question No. 133 (III))

(Los Angeles, 1959)

Question No. 133 (III), § 1, has as its subject "The relation between permissible delay and residual uncertainty and its dependence on bandwidth utilization".

The permissible delay is related to the length of the code (we will suppose that all code characters have an equal number of elements). If the length of the code character is n elements, the delay is at least the time taken by $2n$ code elements. Instead of by the residual uncertainty we will characterize the behaviour of a channel by its error probability. The bandwidth utilization will be determined by the ratio between the number of check digits and the number of information digits, or by the difference between the information rate and the capacity of a channel. (The minimum ratio of check digits to information digits required for efficient use of a communication channel is determined as a function of the capacity.)

For any noisy channel without memory having only a finite number of received signals, the error in transmitting information at a rate $H < C$ and using uniformly good codes of length n is bounded by an expression $F \cdot e^{-(Bn) \cdot (C-H)^2}$ where F and B are constants depending upon the channel parameters, but not upon H or n . This has been shown by Feinstein (1955). H is the information rate and C is the channel capacity. The relation therefore is logarithmic and the coefficient depends on the square of the difference between the rate at which information is sent over a channel and the maximum possible rate.

Shannon (1957) has given more specific results expressed in the distribution function of the transinformation $\rho(x)$. He derives the following theorem: there exists a block code with M messages and a decoding system such that if these messages are used with equal probability, the probability of error is bounded by:

$$P_e \leq \rho(R + \theta) + e^{-n\theta}$$

where θ may be any given positive constant and $R = (1/n) \log M$. Moreover, the optimal detection system gives a probability of error P_e satisfying the inequalities:

$$\frac{1}{2} \rho\left(R - \frac{1}{n} \log 2\right) \leq P_e \leq \rho\left(R - \frac{1}{n} \log 2\right).$$

In older studies of Rice (1950) curves relating the probability of error to the number of digits in a code were already given for some types of random codes, not necessarily uniformly good. Siforov (1956) has calculated the minimum distance of the code characters (the number of elements in which the code characters must differ) as a function of the element error rate and the desired probability of error.

Further results for channels with memory have been obtained by Feinstein and Wolfowitz (1958).

From a practical point of view, all these studies have in common that they give existence proofs for certain codes. The construction of these codes, however, still seems to be out of the reach of even modern calculating machines. After this first problem has been solved, the main

* This Report was adopted by correspondence without reservations (see page 9).

technical difficulty will concern decoding. Only recently Wozencraft (1957) has found more efficient decoding procedures whereby the complexity of this operation goes up slower than the square of the length of the code, instead of growing exponentially with it. Even so the application of these theoretical methods will be an economic problem, where the position may change as the cost of channel capacity goes up, the interest in data transmission increases and the cost of electronic equipment goes down (Fano, 1958).

The other approach, that is to study more completely the properties of relatively short codes (up to 10 elements) has been taken by Slepian (1956). It is however not possible to reach information rates near the channel capacity in this way.

From a theoretical point of view the presence of a return channel does not diminish the probability of error unless the noise in go and return channel should be correlated. The return channel, however, simplifies the coding considerably. Theoretical results for decision feedback systems so far cover only the simplest mathematically tractable models with additive Gaussian noise and possibly Rayleigh fading.

BIBLIOGRAPHY

1. SHANNON, C. E. Certain results in coding theory for noisy channels. *Information and Control*, **1**, 6-25, (1957).
 2. FEINSTEIN, A. Error bounds in noisy channels without memory. *Trans. I.R.E. Professional Group Information Theory*, (Sept. 1955).
 3. RICE, S. O. Communication in the presence of noise. *Bell S.T.J.*, **29**, 60-93, (1950).
 4. SIFOROV, V. I. Theory of ideal coding for binary transmission. *Radiotekhnika i Elektronika*, Moscow, **1**, 407-417, (1956).
 5. FEINSTEIN, A. *Foundation of Information Theory*. McGraw-Hill, 137, (1958).
 6. WOLFOWITZ, D. The coding of messages subject to chance errors. *Illinois Journal of Mathematics*, **1**, (1957), 591-606, Vol. 2, (1958), 137-141, 454-458.
 7. WOZENCRAFT, D. Sequential decoding for reliable communications. *I.R.E. National Convention Record* 1957, **5**, Part 2, (1957).
 8. FANO, R. M. The Challenge of digital communication. *Trans. I.R.E. Professional Group on Information Theory*, **4**, 63-64, (1958).
 9. SLEPIAN, D. A class of binary signalling alphabets. *Bell S.T.J.*, (January 1956).
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REPORT No. 111 *

**INFLUENCE ON LONG-DISTANCE HIGH-FREQUENCY COMMUNICATIONS
USING FREQUENCY-SHIFT KEYING OF FREQUENCY CHANGES DUE
TO PASSAGE THROUGH THE IONOSPHERE**

(Question No. 187 (III))

(Los Angeles, 1959)

1. Introduction.

This report, based mainly on Doc. No. III/34 (U.S.A.) of Geneva, 1958, deals with three aspects of the question. First the magnitude and time duration of the frequency changes to be expected are considered. Secondly, upper bounds of error rates for F.S.K. systems are calculated. Thirdly, experimental element-to-element phase changes are shown, relevant to phase modulation techniques.

The present report gives only partial information on the subject and a more complete study may be expected to provide definitive information on the minimum frequency shift which is feasible in practical systems.

2. Characteristics of frequency changes over H.F. circuits.

It is well known that the rapid fading observed on H.F. circuits is the result of interference between a number of different waves that have been reflected from different portions of the ionosphere. The ionosphere may be thought of as an irregular reflecting surface that is drifting across the sky. Because of this drift, waves that arrive at the receiving site are being reflected from elemental surfaces that are in motion; consequently, each reflected wave will have a small Doppler frequency change. The interference of these frequency shifted waves gives rise to rapid fading. (This report will be concerned only with rapid fading and not slow variations resulting from changes in absorption). This being the case, a reasonable model describing the fading signal is to assume it has the character of very narrow band Gaussian noise. This approach was probably first described by J. A. Ratcliffe [1].

When the narrow band noise representation is used, it is then possible to utilise the extensive work done by S. O. Rice [2] in determining the nature of a fading H. F. signal.

Now the relationship between the fading rate " N_G " (defined as the mean number of times per second the signal envelope passes through the median signal level with positive slope) and the corresponding "equivalent noise bandwidth" of the fading signal is

$$N_G = 1.48 \sigma$$

where σ is the standard deviation of an assumed Gaussian shaped band pass filter. (This equivalent noise bandwidth refers to the received signal only and not the noise that may accompany it). It is equivalent to the 2.17 db half bandwidth of the filter. If a rectangular filter is assumed then the fading rate N_R is

$$N_R = B/2.32$$

where B is the bandwidth of the filter. The Gaussian shaped filter seems to be a close approximation to the true fading bandwidth of an H.F. signal [3], however, for convenience only a rectangular

* This Report was adopted by correspondence without reservation (see page 9).



filter will be considered. Once we have a measure of the bandwidth of the fading signal, we may proceed to find the probability distribution of the instantaneous frequency along with several other statistics.

Fig. 1 shows the cumulative probability distribution of the instantaneous frequency. This curve has been normalised to the fading rate. For a fading rate of one cycle per second, the instantaneous frequency will be within about 20 cycles of the carrier frequency 99.96% of the time.

Taking into account the fading rate indicated in Report No. 159 the values of excursion of instantaneous frequency are not inconsistent with the deviations of 3 parts in 10^6 for a few milliseconds duration reported in Doc. No. III/3 (United Kingdom) of Geneva, 1958.

The mean duration of the instantaneous frequency deviation may be also found with the aid of results worked out by Rice. He derives the expression for the mean number of times per second that the instantaneous frequency exceeds or crosses a given instantaneous frequency when the bandwidth of the filter is known. Taking the reciprocal of these crossings-per-second gives the mean time interval between them. And since we also know the percent-of-time the instantaneous frequency spends beyond the given crossings, we may compute the mean time duration it spends there. This is simply the product of the probability it will be beyond the crossing and the mean time interval between the crossing. This mean time interval, Δt , versus frequency change from the centre frequency is shown in Figure 2. Fading rate is the parameter. If the fading rate is known, the mean duration of exceeding a given frequency change may be found. It is interesting to note that Δt is practically independent of the fading rate.

It should be noted that a more complete study is required to provide the cumulative distribution of the time durations for various specified frequency changes. This is beyond the scope of the present report.

3. The effects on F.S.K. of frequency changes due to passage through the ionosphere.

To determine the effect of frequency changes associated with passage through the ionosphere, we shall assume that no noise is present and that our detector is a frequency discriminator. Our system will make an error if the transmitted frequency is changed far enough to cross over into the wrong side of the discriminator and remains there for a period comparable to half the element length. We shall choose 20 ms as the element length.

If we assume a fading rate of one-per-second and a frequency shift of 40 cycles, we find, referring to Fig. 1, that the frequency of either the mark or space channel will change by 20 cycles and cross over into the wrong side of the discriminator for only 0.04% of the time. The 0.04% represents the upper limit of the binary error rate to be expected in the no noise case. If reference is made to Fig. 2, we find that Δt is only 6.2 ms; consequently, even when the instantaneous frequency does lie on the wrong side of the discriminator its duration is so short that only rarely will an error be made.

Fig. 3 shows the maximum binary error rate to be expected versus the frequency shift of the system with the fading rate as a parameter. It is assumed that errors occur with the probability that the instantaneous frequency has been displaced to the wrong side of the discriminator. This overestimates the true error rate due to frequency changes when the mean length of time of the change is small composed with the signal pulse length, since the discriminator (or post detection filter) time constant has been ignored. As an aid in estimating the region where this time constant becomes effective, points on the curves corresponding to Δt of 10 ms have been located from the curves of Fig. 2.

4. Experimental data relevant to phase modulation.

Several experimental studies have been conducted to determine the performance of the F.S.K. systems and a phase-shift (synchronous) system over sky-wave transmission in the H.F.

band. The phase shift modulation system requires reasonable phase stability over an approximate 44 ms period. Results of these studies are pertinent to this study of Doppler frequency changes.

A short study has been made of the phase stability of signals from WWV as received in Burbank, California [4]. Measurements were made at frequencies of 5, 10 and 15 Mc/s. A sequence of discrete phase comparisons were made at a 50 cycle rate. Each measurement compared the phase of the incoming signals during a 20 ms period with that during the following such period.

Stability of receiving equipment for such measurements is of primary importance. For this test, all receiving gear was frequency controlled by a single high stability local standard (1 part in 10^8) oscillator, thus ensuring that apparent phase shifts due to frequency error were insignificant compared to phase changes due to the propagation.

In general terms, the measuring technique consists of driving an extremely high Q resonator circuit with the received signal for 20 ms. The resonator was then allowed to ring while the second resonator was driven by the signal for another 20 ms. The relative phase between the two resonators was then measured in a phase detector. This resultant measurement was the phase difference between two integration-phase samples taken 20 ms apart. By a suitable connection between two quadrature phase detectors, a polar display of relative phase and amplitude was presented on an oscilloscope face. The oscilloscope intensity level was blanked except at the end of each 20 ms integration period. The resulting display is a series of dots representing the tips of vectors, whose lengths from the origin are proportional to the amplitude of the applied signal, and having angles equal to the signal phase changes between samples. Photographs of these dot displays were made with exposure times of from 15 seconds to 5 minutes. The major results of the study were polar displays of signal phase shift and amplitude. Fig. 4 shows approximate probability contours drawn from these displays. These indicate a decrease in phase stability at higher frequencies, as expected, and give an indication of the degree of phase uncertainty which cannot be attributed to additive noise.

5. Conclusions.

To the degree that the theoretical model describes the behaviour of an H.F. fading signal, it appears that frequency changes imposed by the propagation are small for typical fading rates. This conclusion is supported by some experimental evidence on phase uncertainty obtained over H.F. paths. Further studies, especially of the distribution of the duration of frequency changes are needed to improve the estimates of errors imposed in F.S.K. systems.

BIBLIOGRAPHY

1. RATCLIFFE, J. A. Diffraction from the ionosphere and the Fading of radio waves. *Nature*, **162**, 9. (1948).
2. RICE, S. O. Properties of a sine wave plus Random Noise. *Bell System Technical Journal*, **27**, (1948), 109-157.
3. PRICE, R. The autocorrelogram of a complete carrier-wave received over the ionosphere at oblique incidence. *Proc. I.R.E.*, **45**, 879, (1957).
4. DOELZ, M. L., HEALD, E. T. and MARTIN, D. L. Binary data transmission techniques for Linear Systems. *Proc. I.R.E.*, **45**, 656-665, (May 1957).

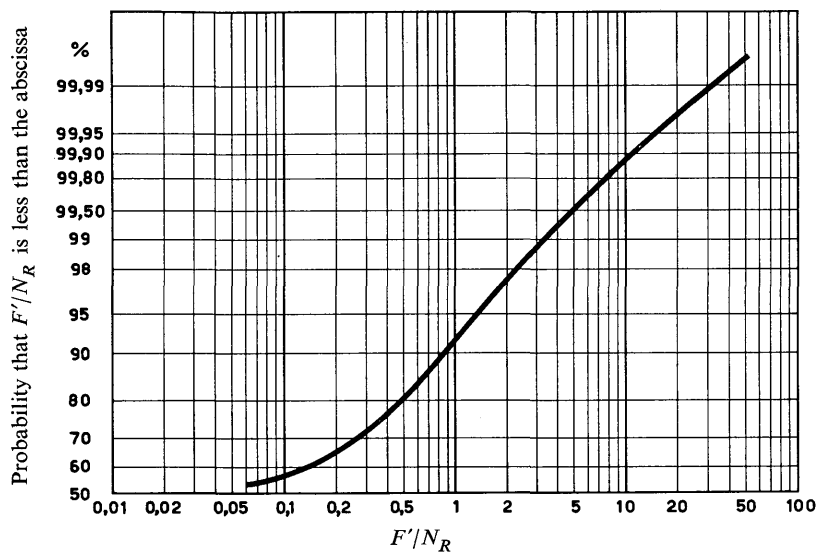


FIGURE 1

F' = Instantaneous frequency change from centre frequency (c/s)

N_R = Fading rate (fades per second)

Cumulative probability distribution of instantaneous frequency change

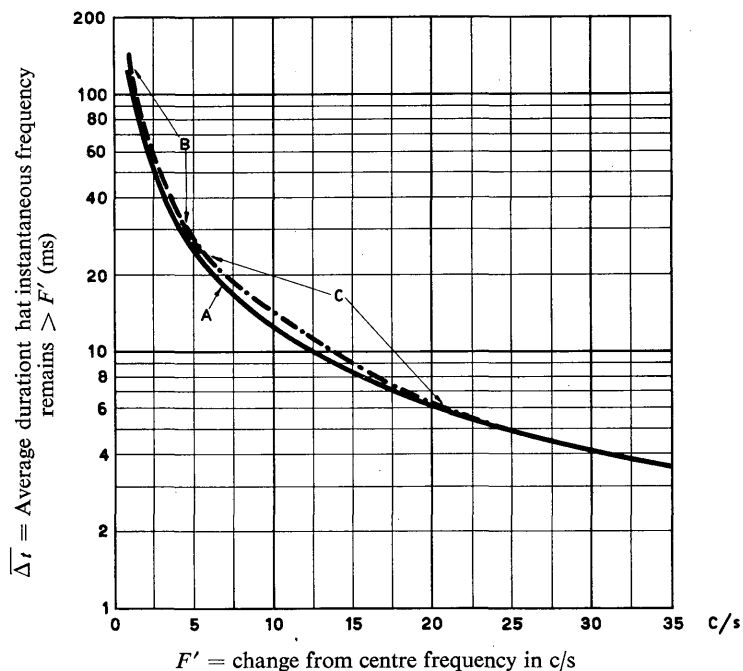


FIGURE 2

Average duration that instantaneous frequency change due to the ionosphere exceeds F' , with fading rates of 0.2, 1.0, and 5.0 fades per second (assuming a model of narrow-band Gaussian noise)

Curve A: 0.2 fades/second

Curve B: 1 fade/second

Curve C: 5 fades/second

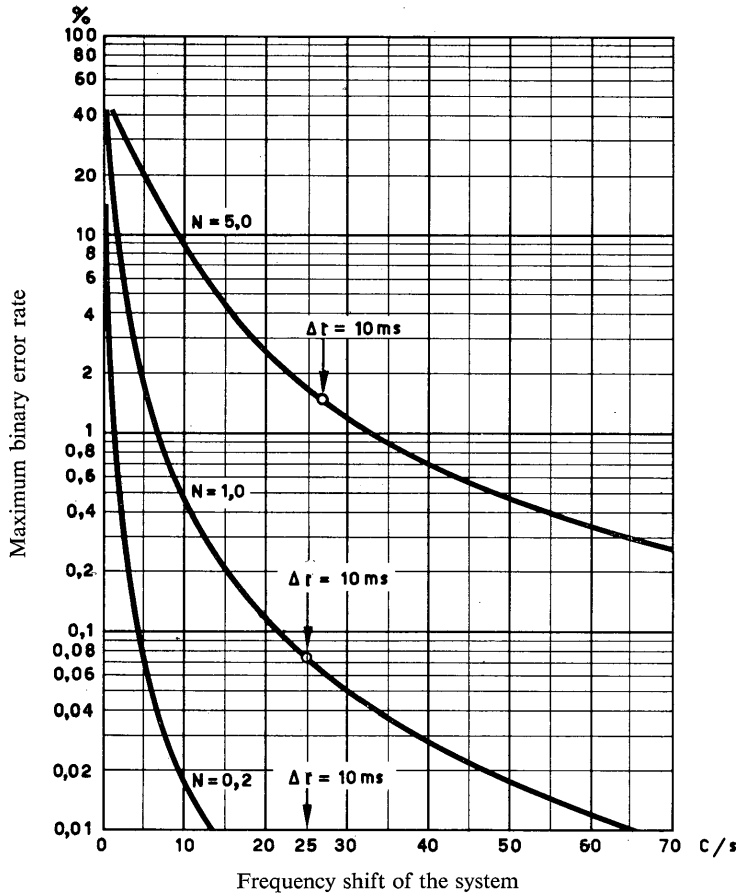


FIGURE 3

Relation between binary error rate and frequency shift of the system for fading rates, N , of 0.2, 1 and 5 fades per second. Element length = 20 ms (50 bauds)

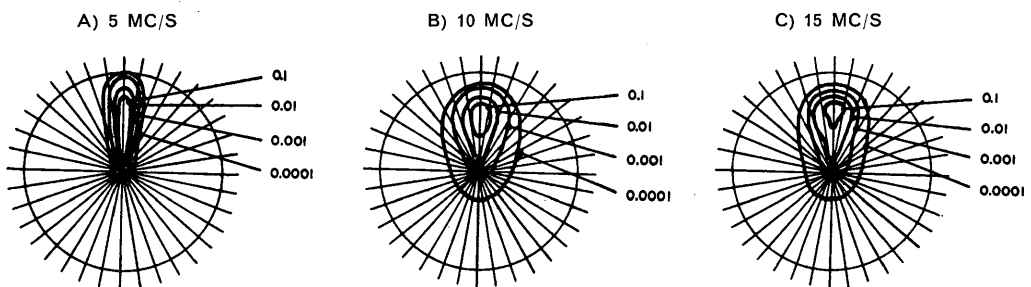


FIGURE 4

Polar Probability Contours of Phase Change and Amplitude of WWV

The members shown represent the probability that a measurement will fall outside the contours.

REPORT No. 112 *

TRANSMISSION LOSS IN RADIO SYSTEMS STUDIES

(Question No. 3 (III), Study Programme No. 128 (III))

(Los Angeles, 1959)

1. Definitions of system loss, transmission loss, basic transmission loss, path antenna directivity gain and path antenna power gain.

Definitions and standard notations ** have been given in Recommendation No. 241 for the system loss L_s , the transmission loss L , the propagation loss L_p , the basic transmission loss L_b , the path antenna directivity gain G_p and the path antenna power gain G_{pp} . It is the purpose of this report to illustrate the use of these terms and the concepts involved, and to show their relationship to other parameters.

2. Transmission loss in free space.

As an example of the simplicity of transmission loss calculations in some cases, we may consider the transmission loss between two isotropic antennae in free space. At a distance, d , very much greater than the wavelength λ , the power flux density (field intensity), expressed in watts per square metre, is simply $p'_t / (4\pi d^2)$ since the power is radiated uniformly in all directions. Since the effective absorbing area of the receiving antenna is $\lambda^2 / (4\pi)$, the available power at the terminals of the loss free isotropic receiving antenna is given by:

$$p'_a = \left(\frac{\lambda^2}{4\pi} \right) \left(\frac{p'_t}{4\pi d^2} \right) \quad (1)$$

Consequently, the basic transmission loss in free space may be expressed:

$$L_{bf} = \log_{10} (4\pi d/\lambda)^2 \quad (\text{free space: } d \gg \lambda) \quad (2)$$

Since the free-space gain of a short lossless electric dipole is $g_t = g_r = 1.5$, the path antenna gain for two optimally oriented short electric lossless dipoles in free space is:

$$G_p = G_t + G_r = 3.52 \text{ db} \quad (3)$$

Consequently, the transmission loss between two optimally oriented short lossless electric dipoles in free space is:

$$L = 10 \log_{10} (4\pi d/\lambda)^2 - 3.52 \text{ db}. \quad (4)$$

3. The concept of propagation loss and the influence of the environment of the antenna.

In order to illustrate the influence of changes in the impedances of the antennae caused by environmental factors which are independent of the antennae circuit losses, we will consider the

* This Report was adopted by correspondence without reservation (see page 9).

** Throughout this Report, capital letters are used to denote the ratios, expressed in decibels, of the corresponding quantities designated with lower-case type; e.g., $P_t = 10 \log_{10} p_t$. P_t is the input power to the transmitting antenna expressed in decibels relative to 1 watt.

transmission loss between two short vertical lossless electric dipoles at heights h_t and h_r , respectively, above a plane perfectly conducting surface and separated by a distance, d , along the surface large with respect to the wavelength. In free space the field strength e , (volts per metre) at a distance d (metres, in the equatorial plane of a short lossless electric dipole radiating p_r (watts) is given by:

$$e^2/\eta_0 = 1.5 p_r/(4 \pi d^2) \quad (5)$$

where $\eta_0 = 4\pi c \times 10^{-7}$ is the impedance of free space (ohms), and $c = 2.997925 \times 10^8$ (metres per second), is the velocity of light in free space. The factor (1.5) can be identified as the free space gain of the transmitting dipole antenna. The radiation resistance of a short vertical electric dipole with effective length l and at a height h_t above perfectly conducting plane is given by:

$$r = \frac{2 \pi \eta_0 l^2}{3 \lambda^2} (1 + \Delta_t) = r_f (1 + \Delta_t) \quad (6)$$

$$\Delta_t = \frac{3}{(2k h_t)^2} \left\{ \frac{\sin(2k h_t)}{2k h_t} - \cos(2k h_t) \right\} \quad (7)^*$$

In the above $k = 2\pi/\lambda = 2\pi f/c$, i.e., λ is the wavelength in free space. Note that Δ_t approaches zero at large heights above the surface and r approaches its free-space value, r_f . On the other hand, $\Delta_t = 1$ for $h_t = 0$, and the radiation resistance is then just twice its free-space value. The field intensity expressed in watts per square metre at a height h_r for a short vertical lossless electric dipole at a height h_t over the perfectly conducting plane surface may be expressed:

$$\frac{e^2}{\eta_0} \approx \frac{1.5 p_r \{ 2 \cos^2 \psi \cdot \cos(kh_t \sin \psi) \}^2}{4 \pi d^2 (1 + \Delta_t)} \quad (8)^*$$

In the above expression $\tan \psi = h_r/d$ and the distance, d , along the surface must be large with respect to both λ and h_t ; in this case, the distance between the antennae is approximately $d/\cos \psi$. Since $\Delta_t = 1$ for $h_t = 0$, the field intensity is 3 db greater when $\psi = 0$ and the dipole is on the surface of a perfectly conducting plane (i.e., $e^2/\eta_0 = 3p_r/(4\pi d^2)$) than when it is in free space; note that in free space we must use [5] and not [8], since the ground reflection influences the radiation for all values of h_t . In more familiar units, when $h_t = h_r = 0$, [8] may be expressed:

$$e = 2.998962 \times 10^5 (\sqrt{p_r}/d) \quad (9)$$

where e is in $\mu V/m$; p_r is in kW; and d is in km.

The effective absorbing area of a short vertical lossless electric dipole receiving antenna at a height h_r above the perfectly conducting plane may be expressed:

$$a_e = \frac{1.5 \lambda^2 \cos^2 \psi}{4 \pi (1 + \Delta_r)} \quad (10)$$

where Δ_r is defined by [7] with h_t replaced by h_r . Since $p_a = e^2 a_e/\eta_0$, we find by combining [8] and [10] that the transmission loss between two short vertical lossless electric dipoles at heights h_t and h_r above a plane perfectly conducting surface may be expressed by:

$$L \approx 10 \log_{10} \left\{ \frac{[(4 \pi d/\lambda) \cos \psi]^2 (1 + \Delta_t) (1 + \Delta_r)}{(1.5)^2 [2 \cos^2 \psi \cdot \cos(kh_t \sin \psi)]^2} \right\} \quad (11)$$

* These relations are derived by S. A. SCHELKUNOFF in Chapters VI and IX of the book *Electromagnetic Waves*, D. Van Nostrand Co., 1943.

$$\text{or } L = L_{bf} + A + L_t + L_r - G_p - 6.02 \text{ (db)} = L_p + L_t + L_r \text{ (db)} \quad (12)$$

where

$L_t = 10 \log_{10} [1 + \Delta_t]$, $L_r = 10 \log_{10} [1 + \Delta_r]$, $G_p \approx 20 \log_{10} [(3/2) \cos^2 \psi]$ and $A \approx -20 \log_{10} [\cos(k h_t \sin \psi)]$. It is of interest to note that the transmission loss between the dipoles on the plane perfectly conducting surface, $h_t = h_r = 0$, is the same as if the dipoles were separated by the same distance in free space, although the field intensity is 3 db greater for the same power radiated. On the other hand, when the dipoles are several wavelengths above the perfectly reflecting surface ($h_t = h_r \gg \lambda$) and are separated by a large distance ($\psi \approx 0$), the transmission loss is 6.02 db less than for dipoles separated by the same distance in free space.

The above is not the only logically consistent method of describing the gains and losses in the presence of a perfectly conducting ground. Thus Schelkunoff in the reference cited considered the perfectly reflecting surface to be an integral part of the transmitting and receiving antennae, and set $G_{ts} = 10 \log_{10} [3/(1 + \Delta_t)]$ and $G_{rs} = 10 \log_{10} [3/(1 + \Delta_r)]$. In other words, he referred his maximum gains to those expected for isotropic antennae with the earth removed; this leads to a path antenna gain, referred to that expected between isotropic antennae with the earth removed, given by $G_{ps} = (G_p + 6.02 - L_t - L_r - A)$, and this transmission loss is simply $L = (L_{bf} - G_{ps})$. However, this method of approach is not recommended since

- it is impracticable to remove the earth in order to measure G_{ps} ,
- it would lead to antenna gains 3 db larger than their free-space values even when they are many wavelengths above a perfectly reflecting plane surface, and this is inconsistent with the present usage of the concept of antenna gain in the higher frequency ranges.

Although it appears to be desirable to separate the effects of earth reflections from the gains of the antennae by means of the propagation loss concept described earlier, there will be other situations in which such a separation of environmental effects is undesirable. For example, the power gain of an antenna mounted on an aircraft, satellite, or space vehicle should be considered as the gain which would be determined by integrating the cymomotive force over all directions as the vehicle is rotated in free space. Equation [12] illustrates the definition of L_p , the propagation loss, i.e., the transmission loss expected if the antennae had the same impedances they would have had if they were in free space. L_t and L_r are defined above for antennae over a perfectly conducting ground plane; more generally, L_t and L_r are defined as $10 \log_{10} (r'/r_f)$ where r' is the actual resistance of the antenna and r_f is the radiation resistance it would have had if it were in free space. We note that L_t and L_r contain the loss components L_{tc} and L_{rc} and also may vary substantially from one antenna site to the next, depending upon polarization and ground conditions. They are also a function of the size of the ground screen used, and depend on other environmental factors such as the presence of trees or over-head wires. It is thus clear why it is desirable to separate these components from the system loss and to have a propagation loss, L_p , independent of these antenna environmental conditions.

4. Simplification possible at the higher frequencies.

At the higher frequencies the antennae are usually located several wavelengths away from the ground and other environmental disturbing elements and, in such cases, L_t , L_r , L_{tc} and L_{rc} will all be sufficiently small so that the propagation loss, the transmission loss, and the system loss will all have essentially the same magnitude, and it will then be unnecessary to distinguish between L_p , L and L_s .

5. Relation to current C.C.I.R. terminology.

It is desirable to relate the above transmission loss terminology to the terminology used in other C.C.I.R. documentation. We may express the free space cymomotive force $C = 20 \log_{10} (e.d)$ in decibels relative to one volt (e.g., relative to one volt per metre at a distance of one metre)

as in Recommendation No. 168. In free space, we find by [5] when we note that $P'_t = P_t - L_{tc}$ and $L_t = L_{tc}$:

$$C = 10 \log_{10} (p_r \cdot c \cdot g_t \times 10^{-7}) = P_t - L_t + G_t + 14.77 \text{ (db)} \quad (13)$$

The relation between the available power, p_a , from the receiving antenna and the field strength, e , may be expressed in decibels as follows:

$$E = 10 \log_{10} [4 \pi \eta_0 p_a (r'/r_f) \times 10^{12}/(\lambda^2 g_r)] = P_a + 20 \log f - G_r + L_r + 107.22 \text{ (db)} \quad (14)$$

where f is in Mc/s.

If (13) is solved for P_t and (14) for P_a and we combine the results, the following expression for L_s is obtained:

$$L_s = P_t - P_a = C - E_C - G_p + 20 \log_{10} f + 92.45 + L_t + L_r \quad (15)$$

where f is in Mc/s.

In Recommendation No. 312, the curves of tropospheric field strength E expressed in db relative to $1 \mu\text{V/m}$ were referred to a free-space electromotive force $C = P_t - L_t + G_t + 14.77 = 46.92$ db relative to one volt (i.e., 222 volts) since they correspond to one kilowatt radiated ($P_t - L_t = 30$) from a half wave dipole ($G_t = 2.15$); thus the propagation loss corresponding to the values of E in those documents is given by:

$$L_p = L_s - L_t - L_r = 139.37 - G_p + 20 \log_{10} f - E \quad (C = 46.92) \quad (16)$$

where f is in Mc/s.

The inverse distance field I (expressed in decibels relative to one volt per metre at one metre) may be determined over a perfectly conducting ground plane from [8]:

$$I = P'_t - L_t + G_t + 20.79 \text{ (db)} \quad (17)$$

Noting that $P'_t = P_t$ over a perfectly conducting ground plane and then solving (17) for P_t and (14) for P_a and combining the results, the following expression for L_s is obtained:

$$L_s = P_t - P_a = I - E_I - G_p + 20 \log_{10} f + 86.43 + L_t + L_r \quad (18)$$

where f is in Mc/s.

In Recommendation No. 307 the curves of $E = f(d)$ were referred to a value of $I = 20 \log_{10} 300 = 49.54$ db relative to one volt, i.e., by (17) the inverse distance field corresponding to one kilowatt radiated ($P_r = 30$) from a short vertical electric dipole ($G_t = 1.76$) over a perfectly conducting ground ($L_t = 3.01$) and thus the propagation loss corresponding to the values of E in Recommendation No. 307 is given by:

$$L_p = L_s - L_t - L_r = 135.97 - G_p + 20 \log_{10} f - E \quad (I = 49.54) \quad (19)$$

where f is in Mc/s.

It is seen from the above discussion that the propagation loss, L_p , may be calculated by (16) from the values of E given in Recommendation No. 312 or by (19) from the values of E in Recommendation No. 307. The fact that there are different relations between L_p and the values of E in these documents illustrates the complexity of the conventions used in past studies of radio wave propagation. There may be some advantage to the C.C.I.R. in adopting the propagation loss, L_p , between short electric dipoles as a standard method of presenting the results of radio propagation studies such as those in the above documents. This would make possible the use of a *single* convention throughout the spectrum and would result in a presentation which is directly useful to those engaged in radio systems studies. Short electric dipoles are suggested as reference standards for the uniform presentation of propagation data throughout the spectrum in preference to either isotropic antennae or half-wave dipoles for the following reasons:

- short electric dipoles are physically realizable throughout the spectrum,
- short electric dipoles have polarization characteristics as do all actual antennae, and
- short vertical electric dipoles have some directivity in the vertical plane and thus simulate typical actual antennae somewhat better as regards ionospheric wave propagation in the lower frequency ranges.

It is recognized that it will often be more convenient at the higher frequencies to make propagation measurements using halfwave dipoles, but such measurements can readily be adjusted to the results expected with a short electric dipole since the maximum gain of a halfwave dipole is just 0.39 db larger than that of a short electric dipole.

If the propagation loss L_p between short electric dipoles were used as a standard by the C.C.I.R., then $G_p = 3.52$ db and the field $E_c = 46.92$ of Recommendation No. 312 could, by (16), be determined from:

$$E = 135.85 + 20 \log_{10} f - L_p \quad (C = 46.92) \quad (20)$$

and the field $E(I = 49.54)$ of Recommendation No. 307 could, by (19) be determined from:

$$E = 132.45 + 20 \log_{10} f - L_p \quad (I = 49.54) \quad (21)$$

where f is in Mc/s in both cases.

6. Comparison between the measurement of field strength and the measurement of the available power from the receiving antenna.

The essential advantage of measuring or calculating propagation characteristics in terms of system loss rather than in terms of field strength is the fact that the former requires the determination of the available power from the receiving antenna for a given input power to the transmitting antenna, and thus automatically allows for both the directivity and the circuit losses of the transmitting and receiving antennas. The available power $p_a = v^2/4r'$, where r' is the resistive component of the receiving antenna output impedance, including both its radiation resistance, r , and loss resistance component, r_c , while v is the open circuit voltage. When the antenna is loaded by the complex conjugate of its output impedance, the voltage appearing across its terminals is $v/2$; thus the available power is simply the power delivered by the receiving antenna to a matched load. The accurate determination of the available power requires the measurement of both r' and v whereas the field strength is independent of r' and, to this extent, does not provide a direct measure of the expected performance of a radio system at least in those cases where the receiver noise is comparable to or larger than the noise picked up by the receiving antenna.

7. Simplicity of systems problems solved in terms of system losses.

Finally, it should be noted that the concept of system loss provides a simple solution to the problem of allowing for the effects of interfering transmissions. Consider, as one example, the determination of the interference to the reception at a particular receiving location of a desired transmitter caused by an undesired transmission on the same channel. The ratio of the desired-to-undesired signal power available at the terminals of the receiving antenna may be expressed:

$$R = P_{td} - P_{tu} - L_{sd} + L_{su} \quad (22)$$

where P_{td} and P_{tu} denote the antenna input powers to the desired and undesired transmitters, while L_{sd} and L_{su} denote the system losses for the desired and undesired transmission paths. When it is noted that the component L_{rc} is the same in L_{sd} and L_{su} , (22) becomes:

$$R = P'_{td} - P'_{tu} - L_d + L_u \quad (23)$$

where P'_{td} and P'_{tu} are the radiated powers from the desired and undesired transmitters, while L_d and L_u are the transmission losses for the desired and undesired transmission paths. Both L_d and L_u will vary with time, and these variations will, over long periods of time, be positively correlated so that the variance of R with time will be somewhat less than the sum of the variances of L_d and L_u . If R exceeds a prescribed minimum acceptable level, R_m , for a sufficiently large

percentage of time, then this particular receiving location may be considered to be free of interference. Note that the effect of the directivity of the receiving antenna is appropriately allowed for in determining R since L_d will be measured (or calculated) with the antenna directed towards the desired station while L_u is the transmission loss corresponding to the effective receiving antenna gain in the direction of the undesired transmitter. In the case of a broadcasting service one may choose a large number of receiving locations within the service area of the desired station in some systematic way* and at each of these locations determine, in the manner described above, whether it is satisfactorily free of interference. This constitutes a useful solution of the problem of assessing the importance of the interference between stations on the same channel; the same method can also be used for interference between stations on adjacent channels simply by changing the value of R_m . It is important to notice that the transmission losses L_d and L_u will be very much influenced by the irregularities in the terrain profiles to the desired and undesired stations, respectively. Furthermore, there will be a tendency for L_d and L_u to be correlated as one moves from one receiving location to the next since unfavourable locations for the reception of the desired station will also tend to be unfavourable for the reception of the undesired station.

The above discussion represents one of a number of possible examples of the utility of the concept of transmission loss in systems studies. There are many circumstances, however, as for example in assessing the interference potential of ISM equipment, where it is more convenient to specify the interference in terms of field strengths rather than attempt to specify the parameters involved in system loss calculations, and it is not the intent of this report to suggest that the concept of system loss should necessarily replace that of field strength. Rather it has been the intent in this report merely to discuss the possible advantages of this concept and to show its relation to other terms in use by the C.C.I.R.

8. Relationship to other C.C.I.R. Questions and Study Programmes.

Note that this method of presenting the results of propagation studies has a direct bearing on the following work of the C.C.I.R.

Questions : Nos. 81 (III), 132 (III), 137 (V), 138 (V) and 184 (V).

Study Programmes : Nos. 57 (V), 84 (I), 89 (V), 128 (III), 130 (III), 139 (V), 144 (VI), 145 (VI), 147 (VI), and 148 (VI).

* It is convenient to choose these receiving locations at VHF frequencies at the intersections of a regular lattice with separations of, say, two kilometres, since it is known that there is very little correlation between the transmission losses at VHF frequencies for receiving points separated by such distances, and this will permit a maximum of information to be derived with a relatively small sample.

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SECTION D

MOBILE SERVICES AND SPACE-SYSTEMS

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REPORT No. 90 *

**PUBLICATION OF SERVICE CODES IN USE IN THE INTERNATIONAL
TELEGRAPH SERVICE**

(Resolution No. 33)

(Study Group No. XIII)

(Warsaw, 1956)

1. In conformity with the C.C.I.T. proposal (Doc. No. 471), the separate volume of codes to be published by the Secretary-General should contain the following documents:

- 1.1 Radio Regulations Appendix 9, Section II: Miscellaneous Abbreviations and Signals.
- 1.2 Radio Regulations Appendix 11, paragraph 3 (1): Spelling Analogy Code.
- 1.3 C.C.I.R. Recommendation 221: Sinpo Code.
- 1.4 C.C.I.R. Recommendation 221: Sinpfemo Code.
- 1.5 The Cable and Wireless Ltd. Facsimile Reporting Code.
- 1.6 C.C.I.T. Recommendation H.1, Article 26: Code Expressions used in the International Telex Service.
- 1.7 The International Telegraph Regulations.
- 1.8 Radio Regulations Appendix 9, Section I: Q-code.
- 1.9 The Cable and Wireless Ltd. Service Code.
- 1.10 The Cable and Wireless Ltd. Z-Code.

2. *Remarks.*

2.1 The documents indicated under § 1.1 to 1.6 inclusive are to be included in the code book without any alteration, on the understanding, however, that one item should be added to the code under § 1.6 viz:

SVH Safety of life telex call

and two items to the code under § 1.1 viz:

SLT Ship Letter Telegram

OL Ocean Letter

2.2 The documents summarized under § 1.7 to 1.10 inclusive are to be included in the code book in part only as indicated below (see § 3).

2.3 The C.C.I.R. is of the opinion that in addition to the code documents mentioned above and proposed by the C.C.I.T. to be included in the code book, there exist one or two very important code documents which are not in the competence of the I.T.U., but nevertheless, are widely in use in the maritime mobile and aeronautical services, (e.g. (a) The International Code of Signals, Vol. II and (b) Communication Codes and Abbreviations published by the International Civil Aviation Organisation). However, their incorporation in the code book would make it too heavy and bulky and in consequence the C.C.I.R. proposes to the C.C.I.T. that only reference be made to them in the code book (see § 7.3).

* This Report was adopted unanimously.

3. *Appendix 2 to Doc. No. 471 (International Telegraph Regulations).*

3.1 The C.C.I.R. is of the view that the suggestion made by the C.C.I.T. as to the part of the International Telegraph Regulations to be inserted in the book should be accepted.

3.2 There is a possibility that the code words taken from the Cable and Wireless Service Code resemble some aeronautical call signs, but this does not seem to be very serious as, to the knowledge of the C.C.I.T., no cases of confusion have ever arisen.

4. *Appendix 3 to Doc. No. 471. (Q-code).*

4.1 The five new code words put forward by the C.C.I.T. are acceptable. They have been notified to administrations by the Secretary-General in his half-monthly Notifications issued since the Atlantic City Radio Conference.

4.2 The C.C.I.R. agrees to the C.C.I.T. suggestion to include only that part of the Q-Code which is reserved for all radio services (QRA-QUZ). The parts (QAA-QNZ and QOA-QQZ) which are reserved for the aeronautical and maritime services respectively, should not be inserted. This suggestion is also supported by I.C.A.O.

5. As to the Cable and Wireless Ltd. code and the Italcable code "Dizionario delle Abbreviazioni Telegrafiche", Appendices 4 and 6 to the C.C.I.T. document, respectively, the C.C.I.R. has no comment. The Appendices should be accepted as they stand.

6. *Appendix 5 of Doc. No. 471 (Cable and Wireless Ltd., Z-code).*

6.1 This code, as stated in the last paragraph of § 8 of the C.C.I.T. document, is widely used in the fixed services.

6.2 Should, however, this Z-code be included in the code book then the telegraph services will be faced with the possibility of confusion with respect to the Z-series of call signs.

6.3 In view of the shortage of call signs, it would be out of the question to withdraw the Z series from the Allocation Table of Call Signs laid down in Article 19 of the Radio Regulations.

6.4 However, as far as the C.C.I.R. is aware, no such confusion has ever occurred in the past, very probably because of the Z-code being used in service messages only.

6.5 The C.C.I.R. therefore accepts the C.C.I.T. suggestion to include the Z-code on the understanding that the C.C.I.R. should re-examine the matter if any confusion with Z-call signs should arise in the future.

7. *Appendix 7 of Doc. No. 471 (Arrangement of material within the code book).*

7.1 In § 2 of Appendix 7 of Doc. No. 471 the C.C.I.T. suggests that the book be divided into three main sections.

7.2 Referring to § 2.3 of this report, the C.C.I.R. accepts that the code documents mentioned there be inserted in the code book in a separate section.

7.3 As, however, they can be considered as belonging to the Miscellaneous Section (see section 4, Appendix 7, Doc. No. 471) it could be divided into two sub-sections, the first sub-section containing Sinpo, Sinpfemo, the Spelling Analogy Code and the Cable and Wireless Ltd. Facsimile Reporting Code (paras. 1 and 2 of Appendix 7), and the second sub-section containing a reference to codes not included in the book e.g. the International Code of Signals, Vol. II and the I.C.A.O. book on communication codes and abbreviations (see § 2.4).

8. Title of the code book.

Taking into account the inclusion of codes relating to the telephone services and the references to non I.T.U. codes, the C.C.I.R. proposes that the C.C.I.T. suggestion concerning the title (page 4, Doc. No. 471) should be amended as follows:

“Codes and Abbreviations for the International Telecommunication Services, published by the International Telecommunication Union.”

9. Unification.

9.1 The C.C.I.R. is of the opinion that it will be necessary for an operational need to be apparent and for operational experience to be obtained, before a study can be made of the unification of codes.

9.2 For this purpose Resolution No. 18 has been modified as follows:

Item 3 of Resolution No. 18 has been deleted and replaced by:

“3. That administrations should consider whether there is an operational need for the unification of codes.” (See Resolution No. 33).

REPORT No. 92 *

MARINE IDENTIFICATION DEVICES

(Question No. 158 (XIII))

(Warsaw, 1956)

1. General.

Two documents, No. 53 (United Kingdom) and No. 71 (United States of America) were submitted to the VIIIth Plenary Assembly in response to Question No. 105 ** on the identification of a response on a marine radar display.

This report summarizes the nature of the problem, the work that has been done, as described in the two documents, and the main points arising out of the discussions at the VIIIth Plenary Assembly.

2. Nature of Problem.

There is a growing use of radar on ships to assist navigation and to prevent collision. Ideally, it would be desirable for radar to give the navigator the same kind of information that he would obtain visually in clear weather. But in the present state of radar development, experience has shown that the radar information might, with advantage, be supplemented by additional information, although there is not, as yet, uniformity of opinion among those concerned with marine navigation, on the type of additional information that would be most helpful to the navigator.

The radar installation on a ship gives, at any instant, only the bearing and position of the other ships. The course and speed of another ship by this means can then be obtained only by plotting; and, in any case, the radar cannot give the future intentions of the other ship. This points to the need for an appropriate communication link as an element of any effective marine identification device employing the types of radar installation in current use.

* This Report was adopted unanimously.

** This Question has been replaced by Question No. 158 (XIII).



An identification device should be unambiguous and should be at least as good as the resolution of the associated radar, so that there would be no confusion concerning the identification of two adjacent echoes on the same bearing or at the same range. The additional information required, for example, might be the call letters of the other ship so that communication could be established; or it might be the course and speed, or the aspect, of the other vessel.

So far, research has been directed towards the development of devices that would identify uniquely a particular echo of a ship on the radar screen of another ship or of a shore-based station. Various proposals, e.g. the use of transponder techniques, have been given in the two documents mentioned and are described briefly in Sections 3 and 4 below.

3. Summary of Doc. No. 53 (United Kingdom).

3.1 Harbour radar identification.

It was considered that suitable devices of the transponder type might facilitate the movement of vessels in the approaches to a port or in a harbour so that the echo of the ship could be identified on the harbour radar and communication established as required. Identification in range and bearing would be essential, so that identification by the use of normal direction finding (bearing only) would not normally be sufficient. There is less likelihood of confusion in harbour radar identification because ships would be identifying themselves to a single harbour radar.

These transponder devices are used in conjunction with a radiocommunication link between the ship and the shore. On the ship either portable equipment of the ship's own radio installation may be used.

Portable radar transponders have been developed which operate in the 3 cm band of the harbour radar. The transporters, and, if necessary, the portable radiocommunication equipment, are taken on board the ship by the pilot. Identification is established by the Harbour Controller requesting the pilot to switch on the transponder, when the response is seen on the harbour radar as a bright line on the bearing of the ship's echo, with a gap, corresponding to 1 mile range, commencing at the ship. The ship is thus identified in range and bearing. The range of the "black-gap" transponder is about 17 nautical miles.

This system would be suitable for use with any harbour radar operating in the 3 cm band and no modification of the harbour radar would be required.

Another type of equipment has also been developed in which the output of a crystal receiver is used to modulate a VHF "walkie-talkie" transmitter which also serves to provide communication with the shore. At the harbour station, the VHF response from the ship is fed into the video stage of the harbour radar. This gives a long radial echo along the bearing of the ship and commencing at a range slightly greater than the ship's echo.

3.2 Inter-ship radar identification.

The former type of transponder mentioned above would not be satisfactory for inter-ship identification because it might well be impossible to establish communication with a particular unknown ship to request that the transponder be switched on; and, moreover, ambiguity would be unavoidable when several independent identification processes were taking place on the same channel.

4. Summary of Doc. No. 71 (United States of America).

4.1 The contribution of the United States, Doc. No. 71 (Warsaw) is based upon limited experience in the use of marine radar identification devices but also covers considerable study of the problem by the R.T.C.M. whose report thereon is attached to the document cited as Annex 3. In summary it is observed that:

4.1.1 there are a number of technical methods for the identification of a radar response as coming from a particular source. All known methods, however, require that the source have an active radar beacon to co-operate with the calling vessel. One solution might be in the direction of a system similar to that used by the military (I.F.F., Identification Friend of Foe) and now coming into use for civil aviation in the United States of America for identification of aircraft to airport radars.

4.1.2 In this type of system each ship-borne radar should be capable of emitting a particular calling or interrogating pulse or code. All vessels would maintain a beacon on continuous alert so that on receipt of the interrogating pulse each beacon would reply with a specific code identifying the vessel. This code when displayed on the interrogating vessel's P.P.I. adjacent to the radar echo from the vessel carrying the beacon would positively identify that echo. Having identified all ships in the vicinity, a radar observer could then contact any one of them directly by whatever communication means are available. Considerable experimentation has been carried out in order to realise a simplified version of this method.

4.1.3 The use of a radar beacon system of the I.F.F. type for marine identification would require considerable expansion of the coding and display features of any equipment known to be currently available. It appears that no attempts to do this have as yet been made in the commercial marine field.

The relatively simplified technique where identification is obtained by energizing the radar beacons one at a time in response to a demand via a communications link, has been reduced to a practical method and considerable related experimentation has been carried out in connection with harbour radar installations. The feasibility of this system has therefore been demonstrated although the necessary beacons are not yet commercially available.

4.1.4 The principal practical aspect is that there is no need to identify a particular radar echo unless it is desired to communicate with the vessel associated with the echo. In narrow congested waters this must be practically instantaneous. This seems to require a radiotelephone circuit connecting the observer of the ship-borne radar directly to his counterpart on the bridge of the associated vessel. Ocean-going vessels, however, are not generally equipped with such means of communication. Further, the multiple language problem requires consideration in any international study of this subject. The Great Lakes area of North America, where nearly all merchant ships are fitted with radar and radiotelephone and navigators speak the same language, is an outstanding exception. Operational investigations of ship to ship identification devices have been carried out therefore only in this area.

4.1.5 The number of vessels involved poses a technical difficulty in adapting an I.F.F. system for marine use, if each vessel were to have a distinct identifying code.

4.1.6 A system of the I.F.F. type in its present form, due to its cost even in a comparatively simple version, presents an economic factor of importance. The complexity of the microwave components which contribute most to the cost of such equipment would be double that required for primary radar alone. The economic factor, however, will undoubtedly be eased as time passes and new technical developments occur, as they have, for instance, in the field of television.

4.2 A number of different types of devices or methods suggested for accomplishing identification of a positive or limited nature are outlined in the R.T.C.M. study referred to above. These include:

- responder beacons of various design,
- passives devices,

D

- D.F. identification using radar antennae,
- suggestions other than identification.

For further details on such types of devices see Annex 3 to Doc. No. 71 (Warsaw).

5. Discussion of documents.

The discussion of the documents has brought out certain important differences in inter-ship identification and shore-based radar identification. In the former case, after the identity of the unknown ship has been established, there may well be difficulty in establishing communication because of differences in language, type of radio installation and watch-keeping. At present, there is no international code on navigational manoeuvres, and "navigation by communication" would probably necessitate revision of the International Rules for the Prevention of Collision at Sea; it would probably raise new legal problems, if for example, a ship were involved in a collision while executing a manoeuvre agreed in advance with another ship. On the other hand, the type of identification which is employed for harbour control does not usually involve such difficulties because the ship has on board a pilot who is receiving advice from, and may communicate with, his own harbour radar station. Rapid identification is also very desirable in all such devices.

An inter-ship identification system would only become effective when the majority of ships were suitably equipped; and it should be borne in mind that the ship does not receive any direct benefit from its own identification device. Thus, ships which themselves do not carry radar are not likely to fit identification devices, particularly if the cost of the device is comparable with that of a radar installation.

6. Future work. *

It was generally agreed in the discussions that it would be most desirable, at this stage, for the C.C.I.R. to obtain from responsible shipping administrative authorities their views on the navigational requirements that should be met by radar identification devices. This is the subject matter of Recommendation No. 222.

It was also felt that the work that had already been done on radar identification, and the differences that had become apparent in inter-ship identification and harbour radar identification, should now be reflected in a revision of Question No. 105: this has been implemented in the new Question No. 158 (XIII), which replaces Question No. 105.

As far as is known, there is no identification device that would fulfil all the probable navigational requirements and the general study will be continued by the C.C.I.R.

BIBLIOGRAPHY

1. PHILLIPS, E. C. Marine traffic coordination. NFAS-ION-RTCA-RTCM Assembly, New York, (Sept. 1950).
2. JANSKY, Jr., C. M., JANSKY and BAILEY. The retarded state of the science of marine navigation. ION-RTCM-Assembly, New York, (Sept. 1950).
3. Merchant Marine Council proceedings, (Sept. 1951).
4. WYLIE, F. J. The use of radar for preventing collisions at sea. Radio Advisory Service, *Journal of the Institute of Navigation (British)*, 6, 271, (1953).
5. WYLIE, F. J. Use of radar to avoid collision. Radio Advisory Service, *Lloyds List & Shipping Gazette*, (Jan. 5, 1954).

* See Resolution No. 61, Vol. II, p. 192.

6. MILWRIGHT, A. P. L. A beacon for ship identification. Royal Naval Scientific Service, *Journal of the Institute of Navigation (British)*, (April 1954).
7. ISBISTER, E. J. and GRISWOLD, W. R. Shore-based radar for harbour surveillance. *Sperry Gyroscope Co.*, Electrical Engineering, Vol. 71, 12, 1072-77, (Dec. 1952).
8. PHILLIPS, E. C., NFAS and ISBISTER, E. J. Marine identification. *Sperry Gyroscope Co.*, RTCM Spring Assembly Meeting, New York, (May 1952).
9. Shore-based radar for New York harbor, a report, *Port of New York Authority*, (August 1953).
10. HARPER, R. B. Pilot boat identification, harbor radar systems. *Sperry Gyroscope Co.*, Paper presented before Western Regional Meeting, Inst. of Nav., Los Angeles, Jan. 23, 1954, to be published in *Navigation*.
11. Symposium papers, of the panel "Radar plus what", delivered at *RTCM Assembly Meeting*, Boston, Mass., 56-70, (Oct. 13-15, 1954).
12. ROBERTS, A. Radar beacons. *MIT Rad. Lab. Series*, Vol. 3, McGraw Hill, (1947).
13. ISBISTER, E. J. RADENT beacon evaluation trials. *Fall Assembly Meeting*, RTCM, Chicago (1953).
14. STOCKMAN, H. Communication by means of reflected power. *IRE, Proc.*, Vol. 36, 10, 1196-1204, (Oct. 1948).
15. RAMARK beacons, U.S. Coast Guard.
16. ISBISTER, E. J. and BUSBY, J. W. RAMARK beacons. *Sperry Gyroscope Co.*, *Navigation*, Vol. 2, 357, (June 1951).
17. MICROWAVE POLARIS, U.S. Coast Guard.
18. You may have the answer. *Merchant Marine Council Bulletin*, U.S. Coast Guard, (Sept. 1953).
19. Unpublished paper of Earl D. GRAY, *McKeel Machine Co.*, Phila., Pa.
20. AUDAR Technical Bulletin, *Radio Industries Corp.*
21. KAMDron, Capt. R. Janus course broadcasting instrument. (Bulletin), Seattle, Washington.
22. Marine identification problem, *final report*, *Special Committee No. 16, Radio-Technical Commission for Marine Services*, Washington, D.C. (See also Annex 3, Doc. No. 71 (Warsaw)).

REPORT No. 93 *

HF (DECAMETRIC) AND VHF (METRIC) DIRECTION FINDING

(Question No. 159)

(Study Group No. XIII)

(Warsaw, 1956)

1. Introduction.

Two documents, No. 67 (United States of America) and No. 232 (United Kingdom) were submitted to the VIIIth Plenary Assembly in response to Question No. 106. A summary of these two documents, and of the discussion on them, is given below.

It was generally agreed that, whenever possible, the accuracy of bearings and positions and their classification, should be based on the probability concept.

* This Report was adopted unanimously.

The U.K. document expresses bearing accuracies in the form of errors that are exceeded on only one occasion in 20 and the U.S.A. document gives the standard deviation error. For ease of comparison of results, all accuracies have been expressed in a common form in this Report.

2. *Accuracy of HF (decametric) bearings.*

The accuracy of HF (decametric) bearings depends principally upon the following factors:

- type of direction finding (DF) equipment, for example, Adcock type,
- type of site,
- frequency,
- range and signal strength,
- ionospheric conditions, particularly diurnal variations,
- amount of interference,
- number of bearings taken,
- skill of the operator.

By day, the error which is exceeded on only one occasion in 20 (referred to subsequently as the 95% error) lies between about 3 and 10 degrees for ranges of the order of 500 to 4000 km, depending on the site, frequency, and whether a group of bearings is taken or only one snap bearing. More detailed data are given in the Annex. At night, errors are somewhat greater, by amounts of up to about 1 degree. At distances less than 500 to 1600 km (depending on ionospheric conditions) the error progressively increases, and may rise to as large as 10 to 20 degrees until the ground wave or the E-layer mode of propagation predominates. In general, errors are less at the higher frequencies.

3. *Accuracy of VHF (metric) bearings.*

In the United Kingdom, the 95% error of VHF aeronautical DF stations is generally about 5 degrees, but in the U.S.A. it has been found that the 95% error is usually about 12 degrees on transmissions from aircraft. The difference is probably due mainly to the effects of differences of siting, since with refinements in siting, the 95% error is reduced to about 4 degrees in the U.S.A. At long ranges, beyond the normal service area, VHF DF bearings in the U.S.A. have been found to be sporadic but the accuracy is sometimes as good as 6 degrees.

4. *Accuracy of HF (decametric) position fixing.*

The accuracy of position fixing depends principally on the "geometry" of the DF network, its size and its disposition with respect to the transmitting station concerned, the degree to which the various stations can take simultaneous bearings and act in unison, and the number of stations in the network. The greatest accuracy is obtained when the most probable position of the transmitting station can be evaluated statistically, although in certain applications it is recognised that statistical evaluation may not be practicable or of operational importance. The accuracy of a DF fix can be expressed in terms of the size, position and orientation of the ellipse in which the transmitting station lies with a given probability. Various methods for deriving and plotting probability ellipses are given in the references in Doc. No. 232 of Warsaw, 1956.

5. *Accuracy of VHF (metric) position fixing.*

The accuracy of VHF position fixing can be determined in a manner similar to that for HF. But in the aeronautical service, which is one of the main users of VHF DF, there is not usually sufficient time to evaluate the accuracy of a fix because of the high speed of the aircraft. At VHF, the problem may be simpler than at HF because the DF networks, in general, will be smaller and can more easily be controlled automatically and have a central automatic display.

6. Classification of bearings in general.

It was considered that it would be very advantageous to have a common classification system of bearings for all frequency bands (MF, HF and VHF) and for all types of service, for example, maritime and aeronautical.

7. Classification of HF (decametric) bearings.

The U.S.A. proposes a subjective method of classification by the operator for describing to the plotting centre the conditions under which a bearing has been taken. The factors that the operator should take into account are strength of signal, sharpness of the null, amount of fading and interference, the amount of goniometer swing required in taking the bearing and the number of bearings that have been taken in the time available. The proposed system of classification is as follows:

Class A — Bearing appears *GOOD* meeting the following requirements:

- (1) strong signal
- (2) definite indication (sharp null, etc)
- (3) negligible fading
- (4) negligible interference
- (5) less than 3 degrees of arc of bearing swing
- (6) observed repeatedly for an adequate period of time

Class B — Bearing appears *FAIR* being degraded by one or more of the following factors:

- (1) marginal signal strength
- (2) blurr (blunting) of indication
- (3) fading and/or audio distortion
- (4) light interference
- (5) more than 3 but less than 5 degrees of arc of bearing swing
- (6) short observation time

Class C — Bearing appears *POOR* being degraded by one or more of the following factors:

- (1) inadequate signal strength
- (2) severe blurr (blunting) of indication
- (3) severe fading and/or audio distortion
- (4) strong interference
- (5) more than 5 degrees of arc of bearing swing
- (6) insufficient observation time

The U.K. proposes that the accuracy of a bearing should be evaluated statistically from a knowledge of the five component variances which make up the total variance of the bearing, namely, instrumental, site, propagation, random-sampling and observational components. The bearing would then be classified as follows:

- Class A: Probability of less than 1 in 20 that the error exceeds 2 degrees
 Class B: " " " " 1 " 20 " " " " 5 degrees
 Class C: " " " " 1 " 20 " " " " 10 degrees
 Class D: Bearings whose accuracy is less than that of Class C.

8. Classification of VHF (metric) bearings.

It was considered that time considerations alone prevent the classification of VHF bearings taken on transmissions from aircraft and it is not possible for the operator to classify bearings. But the U.K. suggested that it would be helpful if VHF aeronautical *stations* were classified, based upon flight-checking procedures. All bearings would then be given the classification of

the station, unless they were taken under conditions inferior to those under which the station was calibrated.

9. *Classification of HF (decametric) position-fixes.*

It was generally agreed that the accuracy of a fix-position should, whenever time permits, be given in terms of probability ellipses. The U.K. proposed that no formal classification be adopted since the size and shape of the ellipse for a given probability depends upon the "geometry" of the network and the transmitting station, the ionospheric conditions, etc. Where time is of essence, the U.S.A. proposed that the most probable fix position would be given in degrees and minutes of latitude and longitude and should be classified as the equivalent circle in which the transmitting station probably lies as follows:

Classification	Limit of Area
Good	40 km, or less, radius
Fair	80 km, or less, radius
Poor	120 km, or less, radius
Estimated	More than 120 km radius

10. *Classification of VHF (metric) position-fixes.*

For the aeronautical service, it was considered that classification in terms of probability ellipses was not likely to be practicable or useful. The U.K. made no proposals on this point; the U.S.A. proposed the following classification:

Classification	Limit of Area
Good	4 km, or less, radius
Fair	8 km, or less, radius
Poor	12 km, or less, radius
Estimated	More than 12 km radius.

11. *Aeronautical aspects.*

It was considered that since VHF DF stations are widely used in civil aviation, administrations should be invited to seek the advice of the International Civil Aviation Organisation on all the aeronautical aspects of VHF direction finding and position finding.

12. *Type of signal for VHF (metric) direction finding.*

In general, the signal for VHF direction-finding purposes should include long dashes of at least 5 seconds duration, but the DF station should also be permitted to specify the duration of the signal in certain circumstances. In the aeronautical service, the procedure laid down by the I.C.A.O. has been found satisfactory. This specifies two dashes of plain carrier, each of approximately 10 seconds duration, followed by the call sign of the aircraft, unless another signal has been requested or is known to be required by the DF station.

ANNEX

APPROXIMATE ERROR (IN DEGREES) WHICH MAY BE EXPECTED TO BE EXCEEDED ON ONLY 1 OCCASION IN 20

- Conditions: — HF Adcock direction finder
 — Daylight
 — Ranges between about 500 and 4000 km.

Type of site	3 Mc/s		6 Mc/s		9 Mc/s	
	Single snap bearing	Mean of 10 bearings taken in 5 minutes	Single snap bearing	Mean of 10 bearings taken in 5 minutes	Single snap bearing	Mean of 10 bearings taken in 5 minutes
Very good	7	6	6	5	6	4
Good, average	10	9	8	7	7	6

REPORT No. 113 *

**SPURIOUS EMISSIONS FROM FREQUENCY-MODULATED
VHF (METRIC) MARITIME MOBILE EQUIPMENT**

(Question No. 161 (XIII))

(Los Angeles, 1959)

Operation of VHF maritime mobile communications might be hampered by interference caused by spurious emissions falling within the band of frequencies used by this service.

Examples of such spurious emissions are mentioned in Docs. XIII/1, XIII/8, XIII/9 and XIII/13 of Los Angeles, 1959.

These spurious emissions may be caused by:

- Harmonics of oscillators of transmitters and receivers.
- Modulation products falling in adjacent channels.
- Intermodulation products produced at receiving stations or generated at transmitting stations and falling in adjacent channels.
- Intermodulation products caused by non-linear elements near the transmitting or receiving stations especially near to two transmitters operating simultaneously and having a frequency spacing of 4.6 Mc/s.
- Parasitic oscillations.
- Transmitter noise.

There are little data available yet about the extent of harmful interference caused by the above-mentioned phenomena and therefore Administrations are requested to continue the study of Question 161 (XIII).

Note. — “Spurious emissions” as used in this report do not include harmonic radiations.

* This Report was adopted unanimously.

REPORT No. 114 *

**CHARACTERISTICS OF EQUIPMENTS AND PRINCIPLES GOVERNING
THE ALLOCATION OF FREQUENCY CHANNELS IN THE VHF (METRIC)
AND UHF (DECIMETRIC) LAND MOBILE SERVICES**

(Question No. 163 (XIII))

(Los Angeles, 1959)

1. Contributions relating to Question No. 163 (XIII) have been received from New Zealand (Doc. XIII/4), Federal Republic of Germany (Doc. XIII/11), Japan (Doc. XIII/30), United Kingdom (Doc. XIII/32) and Sweden (Doc. 180) (Documents of Los Angeles, 1959).
2. While it appears difficult at present to reach complete international standardization of the performance characteristics of land-mobile equipment operating in the VHF and UHF bands, agreement could probably be reached on some common characteristics for certain areas, or certain countries with common borders.
3. Resolution No. 60 therefore invites Administrations to send details of performance specifications of land mobile equipment in operation in their respective countries to C.C.I.R. for circulation
4. The Study of Question No. 163 (XIII) should be continued.

REPORT No. 115 *

**FACTORS AFFECTING THE SELECTION OF FREQUENCIES
FOR TELECOMMUNICATION WITH AND BETWEEN SPACE VEHICLES**

(Questions No. 168 and 169)

(Study Group No. IV)

(Los Angeles, 1959).

The purpose of this report is to summarize the frequency dependence of radio propagation and certain other technical factors which influence communication with or navigation and guidance of space vehicles. The results provide a basis for the selection of frequencies for these purposes. Optimum frequencies can be selected on the basis of the signal-to-noise ratio for a given transmitter power, and of minimum distortion of phase and amplitude, etc. It is recognized that diffraction and other distortions may cause problems in tracking and location; however, the treatment here takes signal-to-noise ratio as the sole criterion for frequency selection.

* This Report was adopted unanimously.

Factors Affecting the Selection of Frequencies.

1. Initially, only modest transmitter power will be available in the space vehicle.
2. All communication between earth and outer space must pass through the earth's atmosphere (including the troposphere and ionosphere). Communication between satellites will primarily involve radio paths outside the influence of the earth's atmosphere.
3. The atmosphere is frequency selective, allowing some frequencies to pass through readily while severely attenuating others. A range of frequencies in which waves readily penetrate the atmosphere is often called a "window".
4. Two principal ranges of frequencies pass readily through the atmosphere. They are:
 - 4.1 The range between ionospheric critical frequencies and frequencies absorbed by rainfall and gases (about 10 to 10,000 Mc/s).
 - 4.2 The combined visual and infra-red ranges (about 10^6 to 10^9 Mc/s).
5. The atmosphere is known to be partially transparent in a third range below about 300 kc/s. Waves are propagated through the ionosphere in this range by what is sometimes called the "whistler mode". Propagation in this mode is not yet well understood.
6. The range 10 Mc/s to 10 000 Mc/s is the most practical for communication purposes considering the present state of development in radio frequency power generation. The upper limit of this range may be as low as 5000 to 6000 Mc/s during heavy rainstorms and the lower limit may be as high as 80 to 100 Mc/s depending upon the degree of solar activity, the location of the earth terminal and the geometry of the signal path. On the other hand, the "window" may extend from as low as 2 Mc/s for polar locations during night-time periods to as high as 50 000 Mc/s at high altitude rain-free locations.
7. In the mid-portion of this "window" favourable propagation conditions exist and circuit performance can be estimated on the basis of free-space propagation conditions by the following relationship:

$$P_t' = \text{Const.} \frac{P_r' f^2 d^2}{G_t G_r}$$

where:

- P_t' = Required transmitter power,
- P_r' = Minimum permissible receiver input power,
- f = Frequency,
- d = Distance between transmitter and receiver,
- G_t = Transmitting antenna gain in the relevant direction,
- G_r = Receiving antenna gain in the relevant direction.

8. Actual propagation conditions vary substantially from this free space assumption at frequencies near the edge of the radio "window", and it is necessary to correct for ionospheric and tropospheric effects to obtain a true estimate of frequency dependence. This correction requires an estimate of tropospheric absorption at the higher frequencies and an estimate of ionospheric absorption at the lower frequencies. In addition to estimating ionospheric absorption, an estimate of the probability of radio signals penetrating the ionosphere must be made.

9. To determine optimum frequencies, the variation of background radio noise within the radio "window" must also be considered:

9.1 Cosmic noise predominates at the lower edge of the radio "window" and decreases with frequency until noise within the receiving equipment predominates.

9.2 At the current state of equipment development receiving equipment noise will predominate between about 100 to 200 Mc/s for antennae directed toward average sky noise areas and between about 300 to 500 Mc/s for antennae directed toward high cosmic noise areas such as the "milky way".

9.3 If low noise receiving equipment such as the MASER amplifier is used, cosmic noise will predominate up to about 1000 Mc/s.

9.4 Noise within the receiver normally increases slowly as the operating frequency is increased.

10. For antennae of fixed physical size, high frequencies have the advantage of greater gain but the disadvantage of narrow beamwidths and associated tracking problems.

11. High speed vehicles travelling so that the distance between transmitter and receiver is rapidly changing, have apparent frequencies differing from the actual transmitter frequencies by the "Doppler" frequency shift.

12. Within the solar system there is evidence of appreciable densities of electrons out to great distances from the sun.

13. Transmission time delay will become substantial in outer space communications, e.g., 2.6 seconds are required for a round trip radio signal to the moon. This time delay is essentially independent of operating frequency.

14. Bolometers have been developed which can detect signals in the optical and infra-red frequency range as low as 160 db below one watt at a "fairly-high rate of signalling".

15. Although great distances are involved, the propagation medium in space beyond the first 800 km (500 miles) of the earth's atmosphere is believed to be essentially transparent to radio waves. Thus we may estimate performance on the basis of free-space propagation. Frequency dependence of receiver input power under free-space propagation conditions depends upon the type of antenna at the transmitter and receiver. This frequency dependence is shown by the following free-space propagation relationship:

$$P_r = \text{Const.} \frac{P_t G_t G_r}{f^2 d^2}$$

where:

P_r is the receiver input power

P_t is the transmitter power

the other symbols have the same meaning as before

Frequency dependence of receiver input power for free-space propagation conditions can be summarized as follows:

15.1 If both the transmitting and receiving terminals of a free-space communication link use non-directive antenna (e.g. two vehicles in space) or if beamwidths at both terminals are fixed, the receiver input signal power increases as the frequency is decreased:

$$P_r = \text{Const.} \frac{P_t}{f^2 d^2}$$

15.2 If one terminal of a free-space communication link uses a directive antenna of fixed physical size and can operate with narrower and narrower beamwidths as frequency increases and the other terminal uses a non-directive antenna or a fixed beamwidth antenna, e.g., a directive antenna on the earth's surface ($G_t = \text{Const. } f^2$) and a non-directive antenna on a space vehicle, the receiver input signal power is independent of frequency.

$$P_r = \text{Const. } P_t/d^2$$

15.3 If both terminals of a free-space communication link use directive antennae of fixed physical size and can operate with narrower and narrower beamwidths as frequency increases, e.g., a directive antenna on the earth's surface, and a directive antenna on a more elaborate space vehicle ($G_t = \text{Const. } f^2$; $G_r = \text{Const. } f^2$), the receiver input signal power increases as the frequency is increased.

$$P_r = \text{Const. } P_t f^2/d^2$$

Discussion.

16. Frequency dependence for practical space-communication circuits requires that atmospheric effects be included. Receiver input signal power and receiver input noise power for a directive receiving antenna and non-directive transmitting antenna are shown in Fig. 1. The receiver input power includes ionospheric and tropospheric effects for a 1600 km (1000 mile) propagation path tangential to the earth's surface for summer midday operation during periods of high solar activity and for moderate rain conditions such as experienced 1% of the time in the Washington, D.C. area. This is typical of the most adverse propagation conditions normally encountered in the absence of sudden ionospheric disturbances, instances of intense sporadic E, areas of auroral activity or rain conditions of cloudburst proportions. During more favourable propagation conditions, such as a propagation path normal to the earth's surface during the night at the lower frequencies, or in a high altitude rain-free location for the higher frequencies, the receiver input power can be expected to be essentially independent of frequency over a wider range of frequencies. The receiver input power as shown between 100 and 500 Mc/s in Fig. 1 will be typical over a much wider frequency range during these favourable propagation periods.

17. Fig. 2 shows essentially the same information as Fig. 1, except that the distance is increased to 48 000 km (300 000 miles), the receiving antenna diameter is increased to 36m (120 feet), the use of cooled amplifiers such as the MASER is anticipated, quasi-maximum values of cosmic noise for high gain antennas are given, and receiver input power for a vertical path in dry rain-free location is shown.

18. Fig. 3 shows the theoretical improvement at the higher frequencies if a directive antenna is used on the space vehicle. Although receiver input power is shown only for a 4.5 m (15 ft) diameter parabolic antenna on the space vehicle, this improvement with increased frequency applies for all directive antennae of fixed physical size. Since the increase in antenna gains at

the higher frequencies more than offsets the slightly increased power requirement due to increased receiver noise at these frequencies, the first impression is that the higher the frequency the better the expected circuit performance as long as the frequency is below the upper limit of the radio "window". (About 6000 Mc/s for oblique paths during moderate rainfall and up to 50 000 Mc/s for high altitude rain-free location). The physical problem of antenna design and tracking, however, establishes minimum permissible antenna beamwidths and is believed to place practical limits on this upper frequency at much lower values.

19. Theoretical effective power requirements for greater distances are shown in Fig. 4 as a function of frequency. Power requirements shown are the minimum detectable radiated power (6 db signal-to-noise ratio) from a space vehicle to a 18 m (60 ft) diameter earth-based antenna under the most adverse propagation conditions normally encountered. Allowances for fading and antenna beamwidth limitations are not shown by the chart. Approximate distances from earth to the moon, the sun, certain planets and to typical man-made satellites are shown.

20. For communication between vehicles in outer space, free-space propagation conditions apply over a wide frequency range. Frequencies above or below the earth's radio "window" can be expected to minimise interference problems with operations on earth. These frequencies will be below about 10 Mc/s or above about 10 000 Mc/s. Selection of an optimum frequency can be based on free-space propagation but requires an estimate of noise powers in outer space, particularly as to the radio noise at frequencies between 2 and 10 Mc/s. Frequencies below 2 Mc/s are considered impractical because of antenna sizes required and the substantial plasma frequencies probably occurring in outer space during periods of severe magnetic storms. If radio noise is excessive below 10 Mc/s and if antenna orientation problems limit the use of high gain antennas, the optimum frequency for communication between space vehicles may fall within the 10 to 10 000 Mc/s radio "window".

21. For space vehicles using essentially omnidirectional antennas communicating with earth terminals using directive antennas, the receiver input power will be constant with frequency over much of the 70 to 6000 Mc/s band and the background noise level and beamwidth requirements to assure tracking determines the optimum frequency. Background noise from sources within the antenna beam (cosmic noise) predominates at the lower edge of the band and noise generated within the first stages of the receiver predominates at the upper edge of the band. The crossover point for the curves representing these noise sources determines the frequency with the maximum signal-to-noise ratio and therefore, the optimum frequency for communication if antenna beamwidths are satisfactory at these frequencies. These optimum frequencies are about as follows:

21.1 100 to 200 Mc/s for conventional receivers with antennae directed toward average cosmic noise sources;

21.2 300 to 500 Mc/s for conventional receivers with high gain antennae directed toward high cosmic noise sources such as the "milky way";

21.3 1000 to 3000 Mc/s if the receiver is equipped with cooled amplifiers such as the MASER;

21.4 Antenna beamwidths must always be considered and compromises made between beamwidth and optimum signal-to-noise ratios. Since receiver noise increases only slowly

with frequency and receiver input power is constant up to about 6000 Mc/s, higher frequencies may be used with only slight decrease in signal-to-noise ratio but at the expense of increased tracking difficulty.

22. As more elaborate space vehicles capable of maintaining attitude and employing directive antennae are developed, the receiver input power will increase with frequency and the background noise level will no longer determine the optimum frequency. The optimum frequency will be governed by a compromise between maximum practical physical antenna size and the minimum beamwidth consistent with acquisition and tracking techniques. If attitude control of the space vehicle and acquisition and tracking limitations of the ground stations establish minimum antenna beamwidths at both terminals, the fixing of the maximum practical antenna size at either terminal will establish the optimum frequency and antenna size for the other terminal. As attitude control and tracking techniques improve, the optimum frequency increases. As larger antennae become practical the optimum frequency decreases. The optimum frequency is therefore closely associated with particular applications and can be selected once the physical antenna size and minimum beamwidths are established. For a one-degree minimum beamwidth for the earth antenna and a 20-degree minimum beamwidth for the space vehicle antenna, optimum combinations of frequencies and antenna sizes are as follows:

Diameter of antenna on earth		Optimum frequency (M/cs)	Optimum diameter of antenna on Space vehicle	
(ft)	(m)		(ft)	(m)
30	9	2400	1.5	0.45
60	18	1200	3	0.9
120	36	600	6	1.8

23. The optimum frequency for communication between outer space vehicles is unknown. It will depend upon radio noise in outer space and upon the ability of the vehicles to maintain attitudes and thereby use directional antennae. For omnidirectional antennae or for any fixed antenna beamwidth the optimum frequency will be the lowest frequency consistent with the practical antenna size and outer space radio noise levels. Since operation at frequencies outside the radio "window" will tend to minimize the radio interference problem between the space vehicles and earth, space vehicles with omnidirectional or broad beamwidth antennae should be assigned trial frequencies below 10 Mc/s if antennae at these frequencies are practical. For more elaborate space vehicles with the ability to properly orient antennae with very narrow beamwidths, operation at frequencies above or near the upper edge of the radio "window" is recommended (above 10 000 Mc/s). If physical antenna size bars the use of frequencies below 10 Mc/s and if the ability to orient the antennae bars the use of frequencies above 10 000 Mc/s, compromises in antenna size and antenna beamwidth will determine optimum frequencies. Frequencies may then be selected by the use of Fig. 4 in the same manner as for communication between space vehicles and earth, when both terminals use directive antennae except that the ionospheric and tropospheric limitations of the earth will no longer apply.

BIBLIOGRAPHY

1. BURGESS, E. *Satellites and Space Flight*. The Macmillan Co. (1957).
2. BEAN, B. R. and ABBOTT, R. Oxygen and Water Vapor Absorption of Radio Waves in the Atmosphere. *Geofisica Pura e Applicata*, Milano, Vol. 37, 127-144, (1957).
3. Radio Astronomy Issue, *Proceedings of the IRE*, Vol. 46, 1, New York, (January 1958).
4. LAITINEN, P. O., and HAYDON, G. W. Analysis and Predictions of Sky Wave Fields Intensity. *Radio Propagation Agency Technical Report No. 9*, (August 1950), U.S. Army Signal Radio Propagation Agency, Fort Monmouth, N.J.
5. NORTON, K. A. Maximum Range of a Radar Set. *Proc. I.R.E.*, (January 1947).
6. CLARKE, A. C. Electronics and Space Flight. *Journal of the British Interplanetary Society*, Vol. 7, 2, 49, (March 1948).
7. SMITH, G. O. Radio Communications Across Space, Ship to Ship, and Ship to Planet. *Journal of the British Interplanetary Society*, Vol. 12, 1, 13, (1953).
8. PREW, H. Space Exploration — The New Challenge to the Electronics Industry. *IRE Transactions on Military Electronics*, Vol. MIL-1, 2, 43, (December 1957).
9. GRIFFITHS. Doppler Effect in Propagation. *Wireless Engineer*, (June 1947).
10. CHVOJKOVA, E. Propagation of Radio Waves from Cosmical Sources. *Nature*, (11 January 1958).
11. BREMMER, H. *Terrestrial Radio Waves*. Elsevier Publishing Company, New York, (1949).
12. CASTRUCCIO, A. Communications and Navigation Techniques of Interplanetary Travel. *IRE Transactions on Aeronautical and Navigational Electronics*, (December 1957).
13. WHEELEN, A. D. Mid-Course Guidance Techniques for Space Vehicles. 1958 *National Conference of Aeronautical Electronics*.
14. MENGEL, J. T. Tracking the Earth Satellite and Data Transmission by Radio. *Proc. I.R.E.*, 44, 755-760, (June 1956).

Designation of the Curves in Figures 1 to 4

- A: Median level of atmospheric noise in high-noise areas (day).
 B: Median level of atmospheric noise in high-noise areas (night).
 C: Minimum frequency assuring penetration of the earth's ionosphere (polar region, vertical path).
 D: Minimum frequency assuring penetration of the earth's ionosphere (polar region, oblique path or tropical region, vertical path).
 E: Minimum frequency assuring penetration of the earth's ionosphere (tropical region, oblique path).
 F: Width of receiving antenna beam (degrees).
 G: Diameter of receiving antenna.
 H: Effect of daytime ionospheric absorption (oblique path, high solar activity).
 J: Typical cosmic noise.
 K: Receiver noise in a receiver of current design.
 L: Effect of rain and gaseous absorption exceeded for one per cent of the time (oblique path, Washington D.C. area).
 M: Average value of cosmic noise.
 N: Quasi-maximum of cosmic noise.
 P: Vertical path in dry rain-free area.
 Q: Oblique path in humid rainy area.
 R: Maser receiver noise.
 S: Oblique path in humid moderately rainy area.
 T: Width of beam of antenna on vehicle (degrees).
- | | |
|-----------------------|-------------|
| a: Sputnik III 1958. | f: Venus. |
| b: Explorer III 1958. | g: Mars. |
| c: Explorer I 1958. | h: Mercury. |
| d: Vanguard 1958. | j: Sun. |
| e: Moon. | k: Jupiter. |
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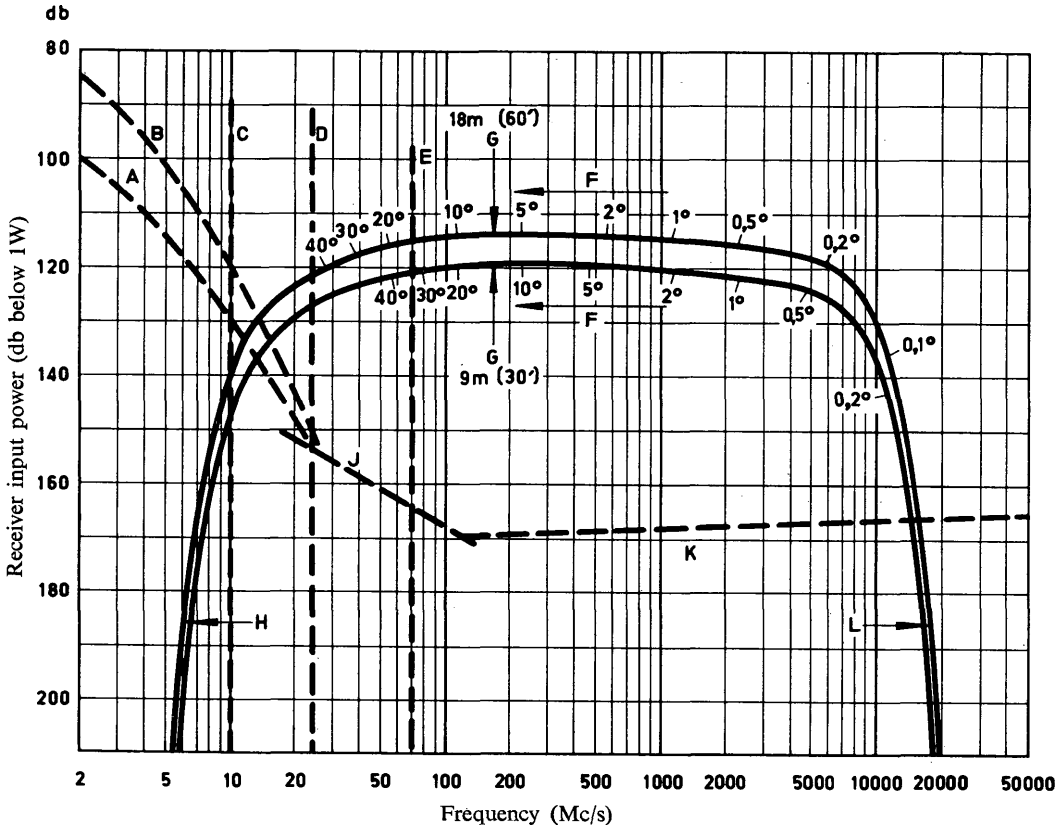


FIGURE 1

Preliminary considerations in selecting frequencies for radio communication to earth from a space vehicle based on 1600 km (1000 miles) (typical satellite distance)

Notes :

Transmitter power — 1W.

Bandwidth — 1 kc/s.

Omnidirectional antenna on vehicle.

Receiving antenna — 9 m (30 ft) and 18 m (60 ft) paraboloids.

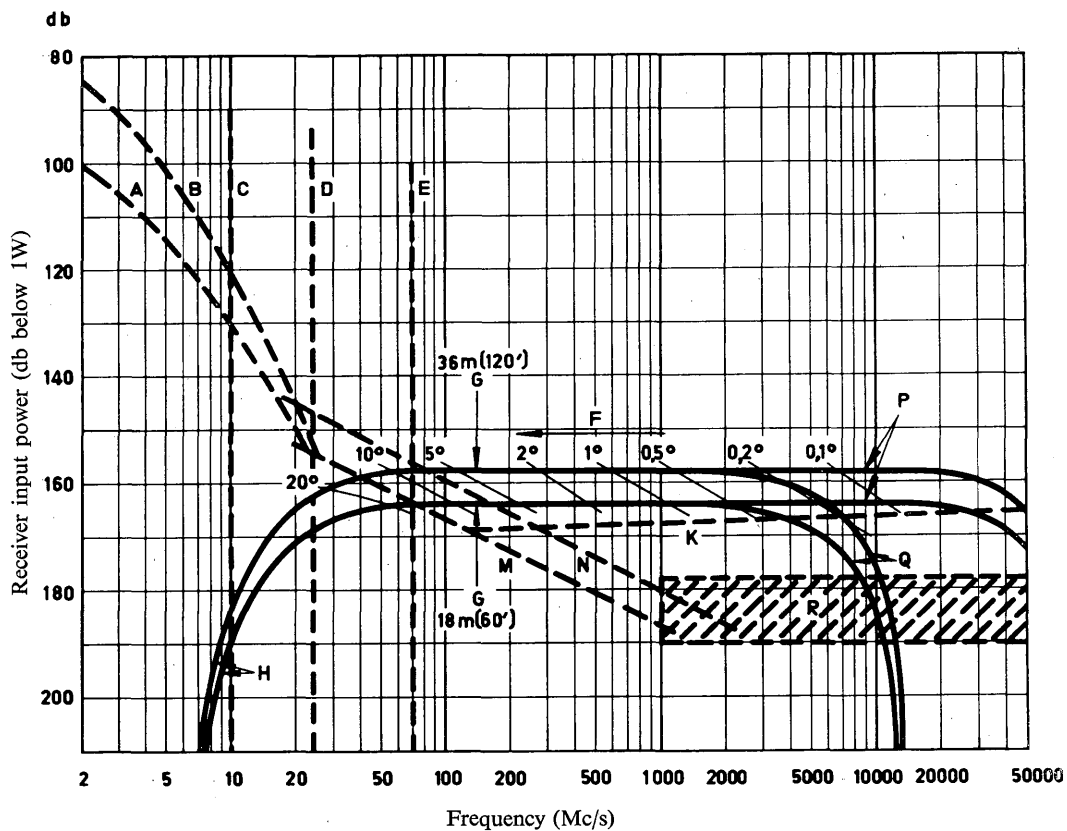


FIGURE 2

Preliminary considerations in selecting frequencies for radio communication to earth from a space vehicle based on 480 000 km (300 000 miles) (distance to circle the moon)

Notes:

Transmitter power — 1W.

Bandwidth — 1 kc/s.

Omnidirectional antenna on vehicle.

Receiving antenna 18 m (60 ft) and 36 m (120 ft) paraboloids.

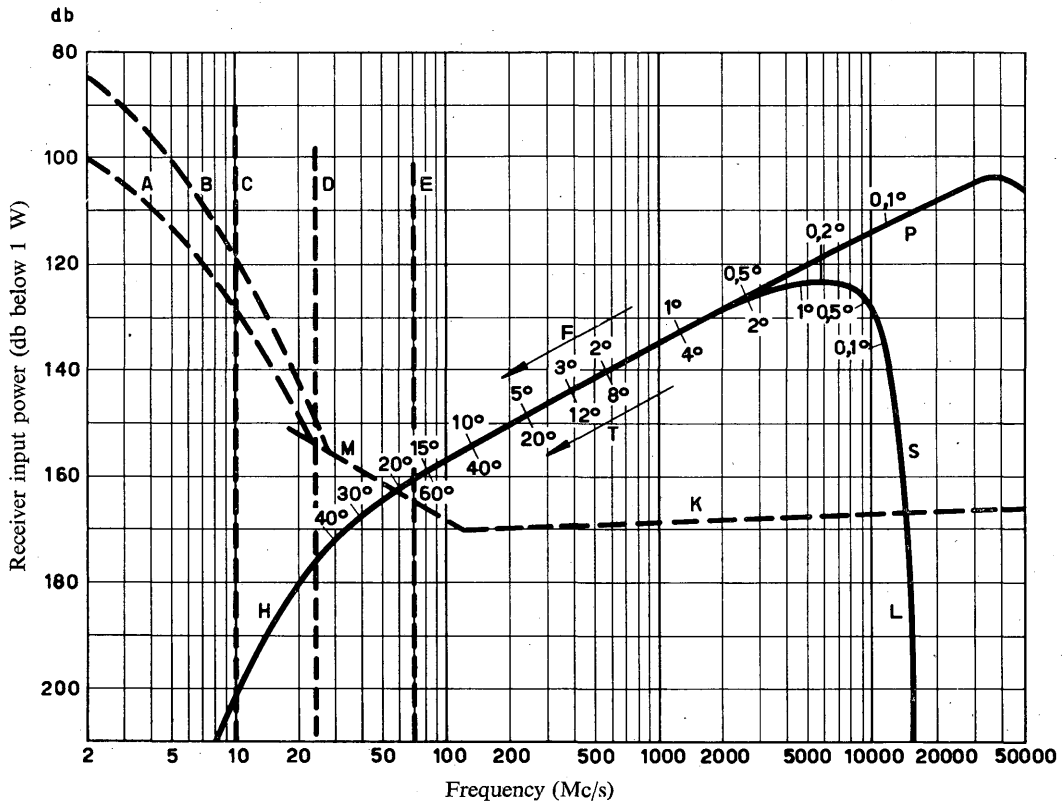


FIGURE 3

Preliminary considerations in selecting frequencies for radio communication to earth from a space vehicle based on 48 000 km (300 000 miles) (distance to circle the moon)

Notes :

Transmitter power — 1W.

Bandwidth — 1 kc/s.

Vehicle antenna — 4.5 m (15 ft) dia. paraboloid.

Receiving antenna — 18 m (60 ft) dia. paraboloid.

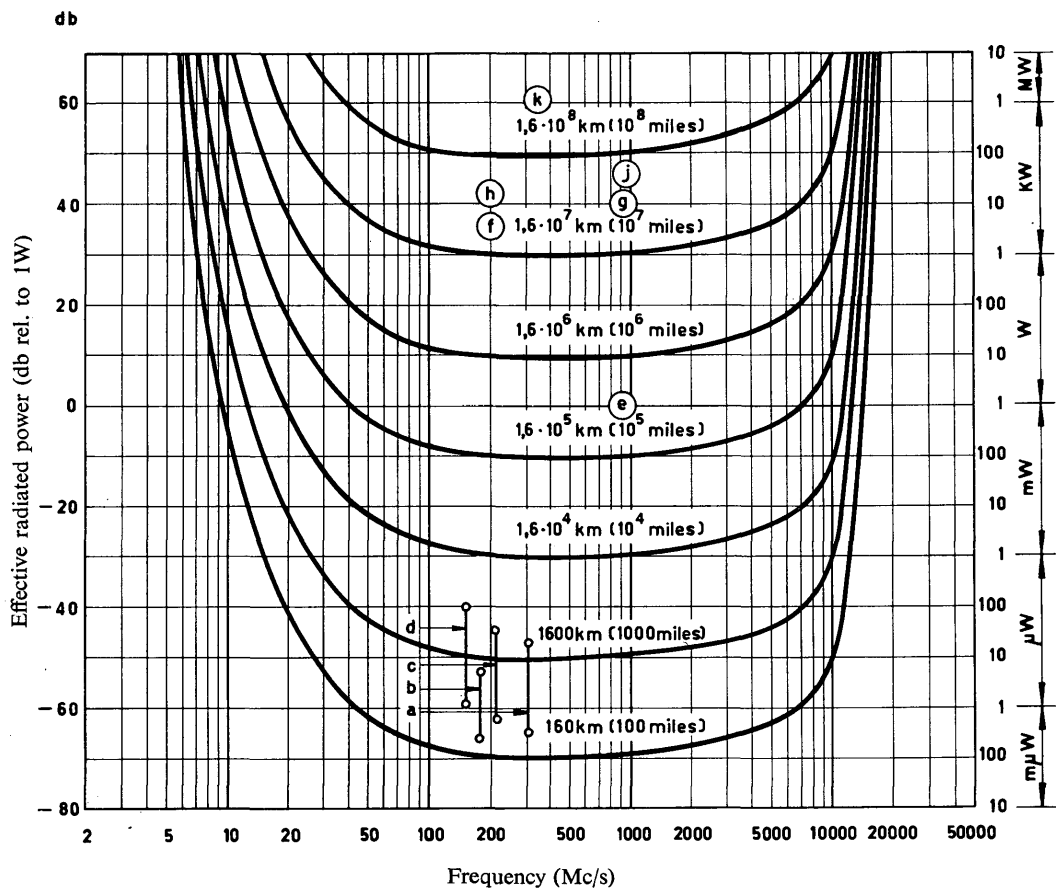


FIGURE 4

Theoretical effective radiated power required from a space-vehicle to permit detection on earth

Notes :

Bandwidth — 1 kc/s.

Signal-to-noise ratio 6 db.

Receiving antenna — 18 m (60 ft) dia. paraboloid. Daytime operation. High solar activity. Rain and gaseous absorption based on 1 % of time. (Washington. D.C.). Radio-path approximately tangential to earth.

Receivers of current design.

SECTION E

SOUND BROADCASTING AND TELEVISION

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REPORT No. 32 *

HIGH-FREQUENCY BROADCASTING

Directional antenna systems

(Question No. 23 (X))

(London, 1953)

Question No. 23 (X) is concerned with the reduction of subsidiary lobes in high-frequency broadcasting directional antenna systems for the purpose of avoiding interference in frequency sharing. This interference is generally caused by the radiation pattern of the transmitting antenna having subsidiary lobes in unwanted directions, or by scatter of the energy of the main lobe, due to propagation anomalies. Reduction in intensity of the subsidiary lobes is possible by correct antenna design, while the propagation scatter in unwanted directions presents a complex problem, and its effect should be treated statistically.

A large amount of work has been done on the properties of directional antennae and on the elimination of subsidiary lobes. Foster [1] has shown that by proper choice of rhombic antenna parameters, optimum subsidiary lobe reduction can be obtained, within a limited frequency range, without significant impairment of the main lobe. A convenient method of design of such an antenna is presented by Laport [2]. Further improvements in subsidiary lobe reduction can be achieved by stacked or coplanar arrays as shown by Christiansen [3, 4, 5]. Such arrays, although more complex, will provide a more satisfactory pattern than a single antenna.

In broadside arrays reduction of subsidiary lobes is in general accomplished to a higher degree than in the rhombic arrays; utilising the binomial distribution [6], the subsidiary lobes can be eliminated to a large extent although the main beam is slightly broadened. A narrower beam with small subsidiary lobes is possible by applying the Dolph-Tchebyscheff distribution [6, 7]. Thus, for a maximum subsidiary lobe intensity 20 db below that of the main lobe, it is possible to get a beam width of 27° . It should be noted that Christiansen [5] attains results from a four-unit array of rhombics which are equivalent to large arrays of tuned elements. He confirmed this on radiotelegraph circuits over a period of some years.

Reduction of subsidiary lobes when the main beam is slewed is a difficult problem as the angle of slew, type of antenna, and distortion of its radiation pattern must be considered. This makes it more difficult to give general rules for subsidiary lobe reduction.

A type of array commonly used [8] consists of four rows of radiating elements, each containing four elements with the lowest row one wavelength above ground. The array is normally provided with a reflector, and the feeder arrangements usually allow for reversing or slewing. The slewing in azimuth of the direction of maximum radiation of this type of array is achieved by the adjustment of the relative phase of the current distribution between the left and right halves of the array. The limit of effective slewing by this means can be taken as 17° on either side of the normal direction, but the amount of slew commonly used does not as a rule exceed 15° .

While this method of slewing does not appreciably affect the horizontal width of the main lobe of radiation, it does increase its asymmetry and at the same time produces a principal sub-

* This Report was adopted unanimously.

subsidiary lobe of considerable intensity. The ratio of the field strength of the main lobe in a slewed array compared with that in the unslewed condition has been determined theoretically; for the type of aerial under discussion the ratios for 0° , 5° , 10° and 15° of slew would be 1.0, 0.98, 0.94 and 0.84. Similarly the ratio of the field strength of the principal subsidiary lobe to that of the main lobe can also be determined and for the same angles of slew would be 0.18, 0.27, 0.45 and 0.7 respectively. These theoretical figures are in close agreement with measured values [9].

Although it is possible, as described in the publications mentioned above, to achieve a substantial degree of suppression of side lobes with either rhombic or curtain arrays, the methods so far employed introduce mechanical difficulties and increase the cost. It is therefore proposed that further consideration be given to the best method of specifying a degree of suppression, for example:

- by limiting radiation in a specified direction, so as to avoid interference in the reception area of another transmission, to a certain proportion of that given by an omnidirectional aerial;
- by limiting the radiation over a wide angle, which excludes the main lobe and any neighbouring strong subsidiary lobes, to a certain proportion of that given by an omnidirectional aerial;
- by limiting radiation in all directions other than those comprised in the main lobe to a certain proportion of that given by an omnidirectional aerial.

BIBLIOGRAPHY

1. FOSTER, D. Radiation from rhombic antennas. *Proc. I.R.E.*, **25**, 1327, (October 1937).
2. LAPORT, E. A. Design data for horizontal rhombic antennas. *R.C.A. Review*, **13**, No. 1, 71, (March 1952). See especially Fig. 4 of this report.
3. CHRISTIANSEN, W. N. Directional patterns for rhombic antennae. *A.W.A. Tech. Rev.*, **7**, 33, (September 1946).
4. CHRISTIANSEN, W. N., JENVEY, W. W. and CARMEN, R. D. Radio-frequency measurements on rhombic antennae. *A.W.A. Tech. Rev.*, **7**, 131, (Dec. 1946).
5. CHRISTIANSEN, W. N. Rhombic antenna arrays. *A.W.A., Tech. Rev.*, **7**, 361, (October 1947).
6. See e.g.: KRAUS, J. D. *Antennas*, First Ed., p. 93, McGraw-Hill, (1950).
7. DOLPH, C. L. A current distribution for broadside arrays which optimizes the relationship between beam width and side lobe level. *Proc. I.R.E.*, **24**, 335, (June 1946).
8. HAYES, L. W. and MACLATRY, B. N. The Empire Service broadcasting station at Daventry, *Journal I.E.E.*, **85**, No. 573, (September 1939).
9. PAGE, H. The measured performance of horizontal dipole transmitting arrays. *Journal I.E.E.*, **92**, No. 18, (June 1945).

REPORT No. 33 *

QUESTIONS Nos. 14 AND 15 OF THE C.C.I.F.

(Study Programme No. 162 (X))

(London, 1953)

Question No. 14.

Many administrations consider that the most significant parameter to monitor at the input of a radiotelephone circuit during transmission is the peak value of the programme voltage. Since however, distortions of very short duration may generally be tolerated, a peak voltmeter with an integration time of up to about 30 milliseconds is commonly used.

Other administrations consider that several parameters ought to be monitored at the input, amongst others the peak value, the mean value and the minimum value, and that the VU type of meter with an integration time of about 300 milliseconds gives an indication that bears a relationship to these values and has been found satisfactory in practice.

The level indicated by a VU type of meter will generally differ from that indicated by a " peak " type of meter by an amount that varies according to the type of programme and which may be 10 db or more.

Question No. 15.

Although there is evidence to show that the present provisional psophometer curve is not entirely satisfactory, it is considered untimely to change it until more comprehensive data are available.

When such data are available it is desirable that a new weighting curve should be formulated, extending to the higher and lower frequencies and if possible in a form that could be obtained by reasonably simple electrical networks.

It is also considered desirable to establish a method of measuring disturbances, the energies of which are concentrated at discrete frequencies.

Note. — This report is to be transmitted to the C.C.I.T.T.

E

* This Report was adopted unanimously. See also Report No. 117.

REPORT No. 75 *

HIGH-FREQUENCY BROADCASTING

Directional antennae with reduced subsidiary lobes

(Question No. 23 (X))

(Warsaw, 1956)

This report summarises the information received by the C.C.I.R. in answer to Question No. 23 (X).

1. General remarks.

The reduction of subsidiary lobes in the radiation patterns of directional antennae made up of radiating dipoles has been theoretically solved by the distribution of currents in the radiating elements using Tchebycheff polynomials. However, this method has serious practical drawbacks (great difficulty in adjusting the antenna, decrease in the radiation resistance of the antenna with a consequent decrease in efficiency). That is why in certain countries attempts have been made to find other more practical solutions without such drawbacks.

As an example, the characteristics of an antenna used in Poland are given below [1].

2. Polish antenna with longitudinal (end fire) radiation and reduced subsidiary lobes.

A block schematic of this antenna is given in Fig. 1 and 2. The current distribution is quite simple: the current has the same value in each of the half-wave elements and the phase difference between two neighbouring elements one quarter-wave apart is 90° .

Fig. 1 shows the connection with the feeder which supplies the two parts of the antenna symmetrically.

Fig. 2 is a diagram of the current distribution equivalent to that in Fig. 1.

This antenna requires no adjustment of current (in amplitude or in phase) for its normal frequency. The input resistance at this frequency is almost entirely ohmic. It is about 600 ohms when the half-wave dipoles are made up of two parallel wires some 25 cm apart.

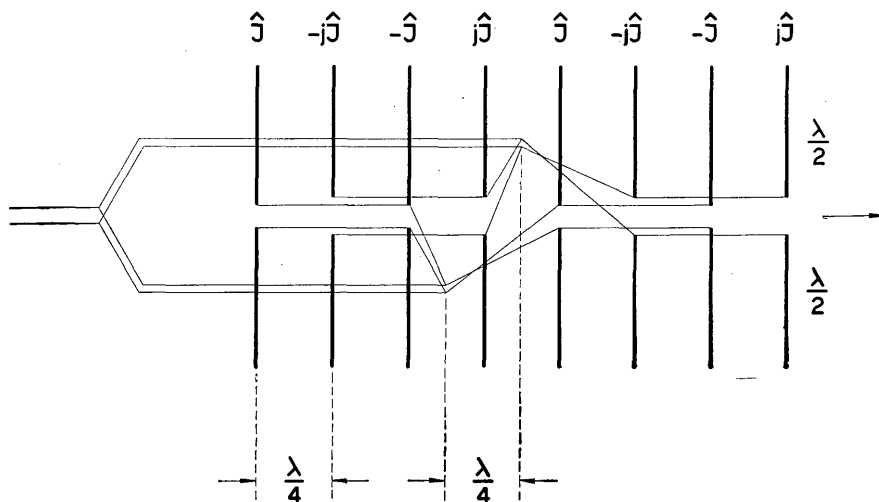
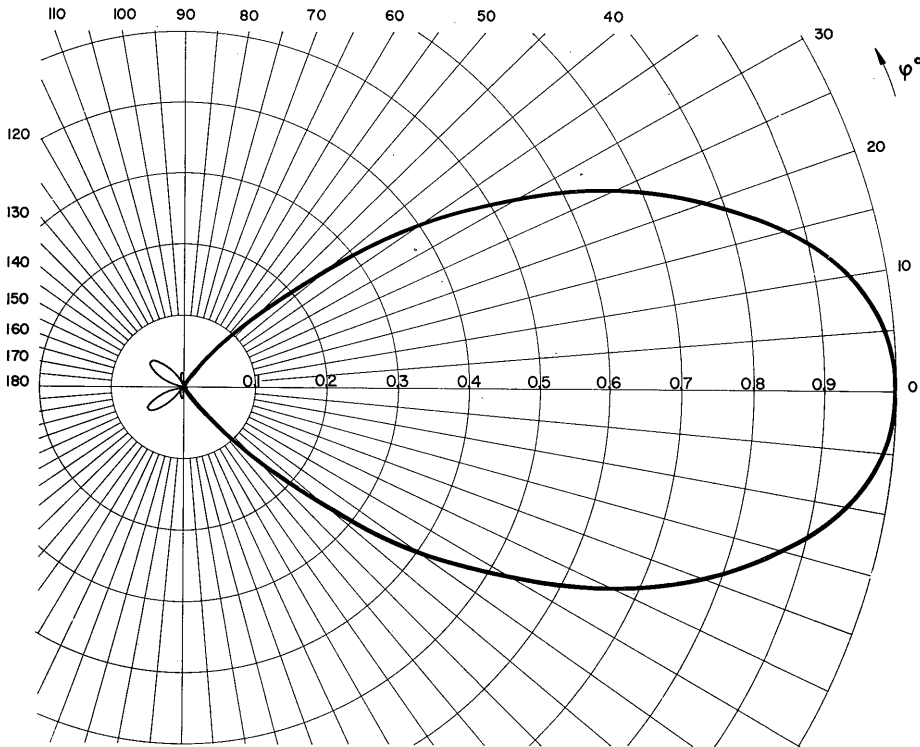
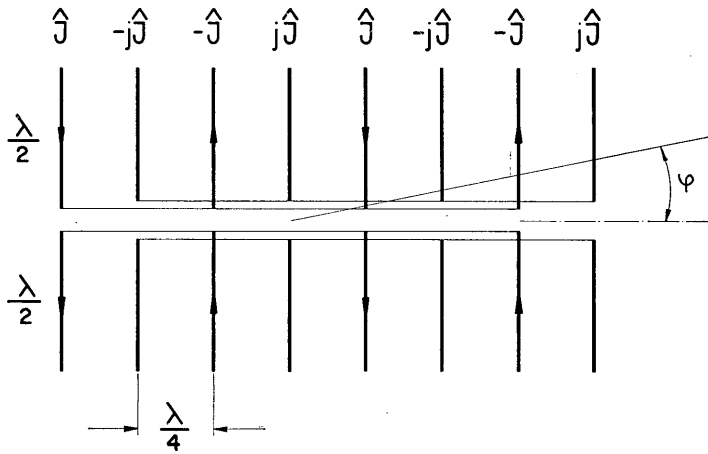


FIGURE 1

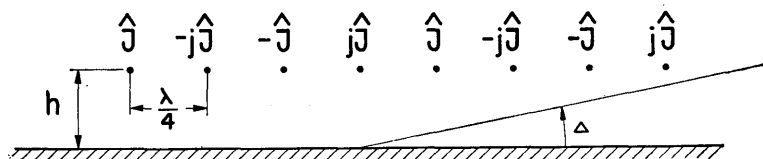
* This Report was adopted unanimously.



$$\frac{E}{E_{max}} = \left| \frac{\cos\left(\frac{\pi}{2} \sin \varphi\right)}{\cos \varphi} \frac{\sin(\pi \sin \varphi)}{2 \sin\left(\frac{\pi}{2} \sin \varphi\right)} \frac{\sin(2 \pi \cos \varphi)}{8 \sin\left(\frac{\pi}{4} \cos \varphi - \frac{\pi}{4}\right)} \right|$$

FIGURE 2

E



$$\frac{E}{E_{max.}} = \text{Const.} \left| \sin \left(2 \pi \frac{h}{\lambda} \sin \Delta \right) \frac{\sin \left(2 \pi \cos \Delta \right)}{8 \sin \left(\frac{\pi}{4} \cos \Delta - \frac{\pi}{4} \right)} \right|$$

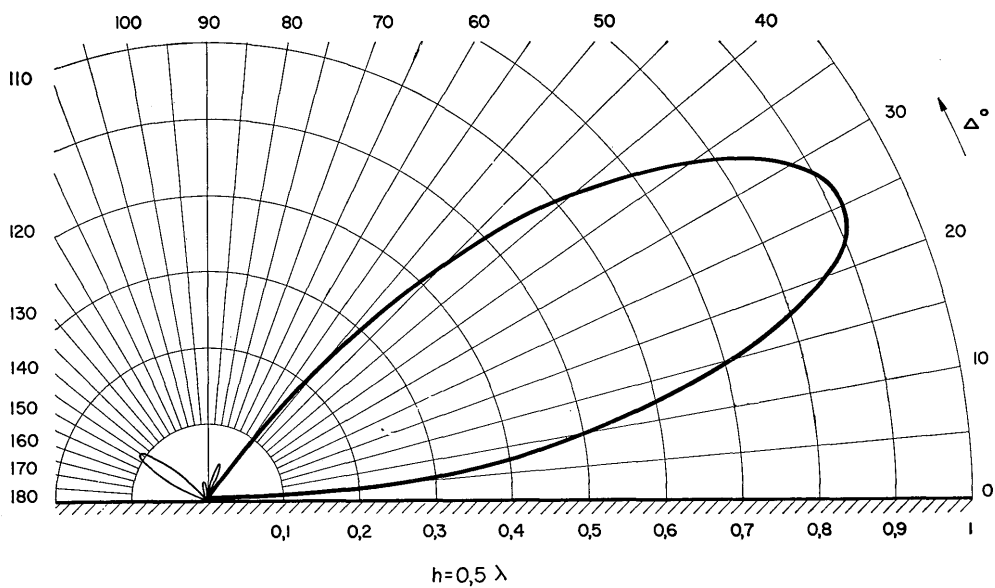


FIGURE 3

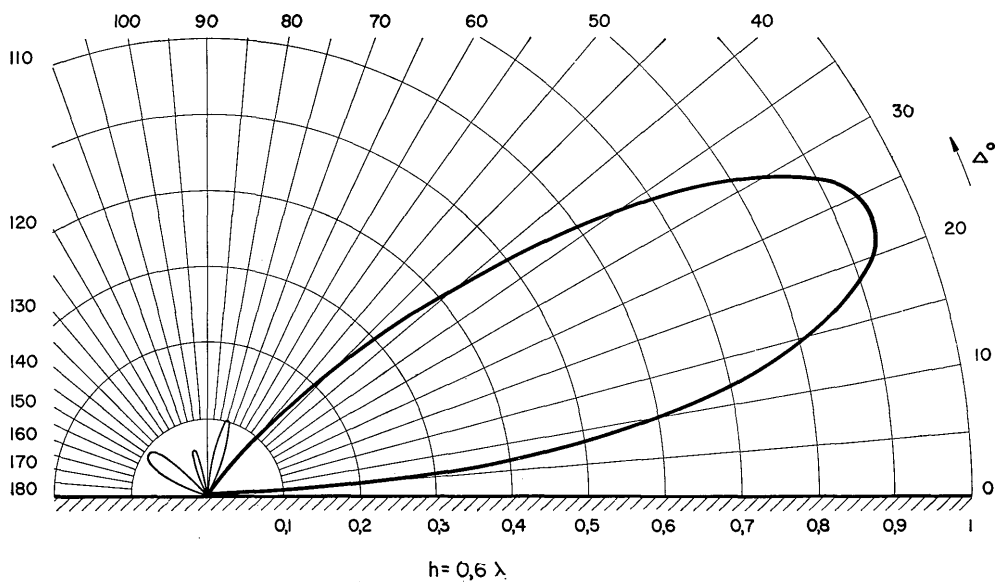


FIGURE 4

The radiation diagrams show that the reduction of the subsidiary lobes is quite satisfactory. Fig. 2 is the horizontal radiation diagram in the purely theoretical case when the antenna is situated in free-space, the effect of the ground being neglected.

Fig. 3 and 4 are the vertical radiation diagrams for an antenna height of about one half-wave.

The horizontal and vertical directivity formulae are given in Fig. 2, 3 and 4.

In this new antenna, the absorption resistor has been eliminated and the efficiency is thus very nearly unity.

This antenna also has the great practical advantage of having a radiation diagram that can be slewed by 180°.

This type of antenna has been used in Poland since 1950 for broadcasting the European programme on high frequencies.

Fig. 1, 2, 3 and 4 should be published in the C.C.I.R. collection of antenna diagrams.

BIBLIOGRAPHY

1. Doc. No. 208 of Warsaw, 1956.
2. MANCZARSKI, S. Report on the longitudinal radiation antenna from the viewpoint of short-wave European broadcasting requirements, 1950 (in Polish).

REPORT No. 77 *

FREQUENCY-MODULATION SOUND BROADCASTING IN THE VHF (METRIC) BAND

(Question No. 150 (X))

(Warsaw, 1956)

In the study of Question No. 99** at the VIIIth Plenary Assembly, it became evident that not enough experience had yet been available to determine the protection ratios required in Item 3 of the Question. The following figures were examined:

	(1)	(2)	
For co-channel working	20 db	26 db	} for 99% of the time
For carriers spaced at 100 kc/s	10 db	10 db	
" " " 200 kc/s	0 db	6 db	
" " " 300 kc/s	— 10 db	0 db	
" " " 400 kc/s	— 20 db	— 12 db	

Figures under (1) resulted from tests with receivers provided with a suitable limiter proceeding the discriminator or ratio detector and with characteristics:

kc/s off-tune	0	50	100	200	300
response (db)	0	0	— 3	— 20	— 36

Figures under (2) resulted from tests using about 20 different types of receivers and are an average of the results.

A figure of 30 db for co-channel working was also proposed as necessary to give an entirely satisfactory quality and in fact to give a quality superior to the minimum quality required for the sound channel in television (Report No. 125, § 5).

The study of this problem will be continued (Question No. 150 (X)).

* This Report was adopted unanimously.

** This Question has been replaced by Question No. 150 (X).

REPORT No. 79 *

STANDARDS OF SOUND RECORDING FOR THE INTERNATIONAL
EXCHANGE OF PROGRAMMES

(Study Programme No. 161 (X))

(Warsaw, 1956)

In conformity with the recommendation appearing in § 3 of Study Programme No. 161 (X), exchanges of test tapes have taken place during 1954 and 1955 between a number of broadcasting organisations. The results obtained have been reported in the following Warsaw documents:

No. 198 — France,

No. 235 — United Kingdom,

No. 292 — E.B.U.,

No. 374 — Japan (including comments from Denmark, France, Federal German Republic and Switzerland).

The results obtained have made it possible to assess the practical validity of the measuring methods described in Recommendation No. 261 and its Annex. Thus, it is now possible to exchange programmes recorded on magnetic tape at tape speeds of 15 and 7.5 ins/sec. with the assurance that the technical quality will correspond to the standard indicated in § 9 of Recommendation No. 261.

In the course of these exchanges, however, certain discrepancies have been observed for the extreme frequencies. These discrepancies are more systematic at low frequencies and seem to be due to the method of measurement.

A study of these discrepancies has shown that they can all be attributed to a difficulty in applying the definition of the "ideal head" as it appears in § 9 of Recommendation No. 261.

Since an ideal reproducing head is defined as a ferromagnetic reproducing head, the losses of which are negligible, it is important to know precisely the losses of heads normally used in order to construct a reproducing system equivalent to an ideal head.

Recommendation No. 261 mentions explicitly two types of losses:

— those dependent on frequency,

— those due to the gap length,

and in the Annex to Recommendation No. 261 practical methods are given for measuring these.

During the exchange of test tapes, it was found that in certain cases attention should be given to other losses, for example, those due to the imperfect contact between the tape and the head, and those due to the dimensions of the core of the ferromagnetic head.**

It is not impossible that in the future new causes of losses may be discovered.

For these reasons it will be necessary in the future to decide on a new wording that will eliminate the concept of the ideal head and will define only the state of magnetisation of the tape, and indicate methods for measuring this for all frequencies.

It appears that the study of these problems is not yet sufficiently advanced to permit this change to be made now. It has therefore been considered preferable to leave the Recommendation in its present form, adding only a note which describes the nature of the errors likely to be encountered at very low frequencies, and the means of avoiding them.

The study of the problems should be continued.

* This Report was adopted unanimously.

** These losses, as well as those dependent on frequency, can be negative as well as positive.

REPORT No. 81 *

**SOUND RECORDING ON FILM FOR THE INTERNATIONAL
EXCHANGE OF TELEVISION PROGRAMMES**

(Question No. 100)

(Study Group No. X)

(Warsaw, 1956)

In reply to Question No. 100, the VIIIth Plenary Assembly of the C.C.I.R. has adopted Recommendations Nos 264 and 265 which recommend methods to be used for recording sound on film for the international exchange of television programmes.

It has been recognised that in certain cases it would be desirable to use a second film, distinct from the picture film, for the recording of one or more additional sound tracks. This second film would be particularly useful in the following cases:

- (a) when the sound recorded on the picture film contains elements that cannot be retained (e.g. dialogue in a foreign language). In this case, one of the two films would carry the original sound and the other the "international" sound, by which is meant the sound that has no linguistic content (music and sound effects);
- (b) whenever it may be desirable to record several sound tracks simultaneously;
- (c) when only one sound track is needed, but the stripe at the edge of the film, for some reason, cannot be used;

Furthermore, apart from the question of programme exchange, the use of a separate film for sound recording is often necessary when carrying out processing operations such as copying, mixing and editing.

It is desirable that the characteristics of this second film should be standardized, particularly in regard to the number, dimension and position of the tracks, but for the following reasons, it has not been possible, to set up standards:

- the techniques are not yet fully developed,
- the characteristics used in different countries are not sufficiently known.

In order to facilitate the exchange of programmes, the C.C.I.R. proposes that when use is made of both picture film and magnetic sound film,

- (a) the films should both be 16 mm and the mean speed of both picture and magnetic sound films should be identical;
- (b) the recorded sound track should be: a 2.5 mm-wide track at the edge of the film, placed in the same position as the magnetic stripe on the film (Recommendations Nos 264 and 265), or a 5 mm-wide track placed along the physical centre of the film.

In all cases the recording characteristic should be that defined in § 9 of Recommendation No. 261 for a tape speed of $7\frac{1}{2}$ inches/second (19.05 cm/s).

Until a definite standard on this question has been set up the choice of the track to be used and whether or not single or double perforated sound film is to be used should be agreed upon by the organisations concerned. Furthermore, in each case where a second film is necessary in the exchange of a programme the track or tracks that are used and, if necessary, the nature of the sounds recorded thereon, should be clearly indicated.

It has been resolved that further studies on this question should be carried out in collaboration with other international organisations (I.E.C. and I.S.O.) so that a definite standard can be achieved as soon as possible.

* This Report was adopted unanimously.



REPORT No. 86 *

DESIGN OF TRANSMITTING ANTENNAE FOR TROPICAL BROADCASTING

(Question No. 70)

(Study Group No. XII)

(London, 1953 — Warsaw, 1956)

This Report summarizes the information submitted to the C.C.I.R. in answer to the three questions to be studied under § 1, 2 and 3, of Question No. 70.

1. The transmitting antenna should be situated as near to the centre of the reception area as possible.

For antennae relying on ground reflection for their vertical directivity the site should be chosen where the soil is of good conductivity, though, in cases where this is not possible, an earth mat can be used. This could consist of a number of parallel wires spaced not more than one tenth of a wavelength apart, parallel to the dipoles and extending for half a wavelength beyond the extremities of the antenna array.

Where it is not possible to site the antenna at the centre of the reception area, it is possible, with multi-element transmitting antennae, to slew the beam away from the vertical in the direction of the main reception area (see Annex). Angles of slew greater than about 15 degrees often produce large side lobes which may cause interference outside the reception area.

If there are no adjacent reception areas, for example, where the area to be served is an isolated island, central siting is less important.

2. The transmitting antenna for tropical broadcasting should be designed to produce a more or less uniform field, with no skip zone, and of as high a value as possible throughout the reception area. Beyond this area the field strength should decrease as rapidly as possible. The antenna should be economical in design and simple in operation.

The antenna should therefore be designed to produce the greatest high-angle radiation possible consistent with adequate radiation down to the angle of radiation used to serve the fringe of the service area (see National Bureau of Standards Circular No. 462, p. 106). Thus for instance, a service area having an outer radius of about 800 km may require a low directivity antenna consisting of a simple dipole between a quarter and a half wavelength above earth but, for smaller areas, more directive multi-element antennae would be desirable in order to reduce the low-angle radiation ** (see Annex).

It is considered desirable that the C.C.I.R. should include the curves shown in the Annex, or similar ones, in its antenna charts. ***

It is possible that the siting of the transmitting antenna used for tropical broadcasting with respect to the magnetic meridian has an influence on the field produced by reflection from the ionosphere. It is therefore requested that in answer to Question No. 154 (XII) dealing with propagation in the tropical zone, reference should be made to this point.

3. For the great majority of domestic tropical broadcast listeners only simple antennae are possible and the directivity of such antennae cannot be relied upon to improve the signal-to-noise ratio.

* This Report replaces Report No. 36 (see Report No. 87).

** "High-frequency broadcast transmission with vertical radiation", P. ADORIAN and A. DICKENSON, *Journal of the British Institute of Radio Engineers*. (February 1952).

*** See "Supplement No. 2 to the antenna charts of the C.C.I.R.", published by the I.T.U., Geneva, December 1958.

The antenna has to be both cheap and simple to install and has to be used on a number of frequencies, with fields corresponding to varying angles of incidence. It appears reasonable to assume that the average listener's antenna cannot be better than that given in the report of the Geneva Planning Committee; this consists of an L type aerial with horizontal and vertical limbs 16 feet in length (4.80 metres).

ANNEX

NOTES ON THE PERFORMANCE OF ARRAYS OF HORIZONTAL DIPOLES ARRANGED FOR VERTICAL INCIDENCE

1. General.

Arrays of this type consist of a number of rows of $\frac{\lambda}{2}$ dipoles end to end, the rows being $\frac{\lambda}{2}$ apart, and all the same height above ground. In passing, it should be noted that the simplest case of all, that of a single dipole, is the array of this type most commonly in use. For a complete knowledge of the performance of such an array the vertical polar diagram should be known for all angles of azimuth. In practice, however, a knowledge of two polar diagrams, that in the vertical plane containing the dipoles, and that in the vertical plane at right-angles to the dipoles is sufficient to estimate the performance.

2. Polar diagrams.

Figs. 1, 2 and 3, show diagrams in the two vertical planes for three types of array:

Fig. 1 — A single dipole.

Fig. 2 — Two rows, each of two dipoles.

Fig. 3 — Four rows, each of four dipoles.

The diagram in the vertical plane parallel to the dipoles depends solely on the number of dipoles in a row. The diagram in the plane at right-angles to the dipoles depends solely on the number of rows of dipoles. It is thus possible from the diagrams shown in Figs. 1, 2 and 3 to assess the performance of arrays with up to four dipoles per row and up to four rows of dipoles. For example, for an array consisting of two rows each of four dipoles, the diagram in the plane containing the dipoles would be that of Fig. 3, curve (a) and the diagram in the plane at right-angles to the dipoles would be that of Fig. 2 curve (b).

3. Height of array above ground.

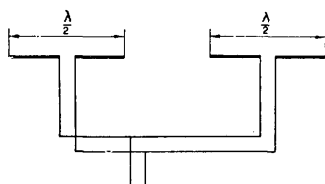
For the vertical radiated field to be a maximum, the optimum height of the dipoles above ground is $\frac{\lambda}{4}$ but the height is not critical. Figs. 1, 2 and 3 correspond to a height of 0.2λ above ground, but each of the curves shown may be converted to apply to any height of h wavelengths above ground, by multiplying by:

$$\frac{\sin (2 \pi h \cos \theta)}{\sin (0.4 \pi \cos \theta)}$$

4. Slewing.

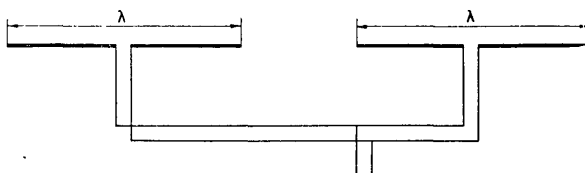
The diagrams shown in Figs. 1, 2 and 3 assume equal co-phasal currents in all the half-wave dipoles, and as may be seen, this results in a diagram suitable for a station situated in the centre of the service area. If it is desired to site a station away from that area, the direction of the vertical beam can be slewed by dividing each row of dipoles of the array into two halves and driving these two halves with currents in different phases. It follows that the array of Fig. 1, a single dipole, cannot be slewed.

This method of slewing is most easily applicable to arrays of two or four dipoles per row and the following sketches indicate the method of feeding:



Bay feeder offset
from centre

Slewing of array
2 dipoles wide



Bay feeder offset
from centre

Slewing of array
4 dipoles wide

This method of slewing results in the main lobe being slewed in the plane containing the dipoles, whilst the polar diagram in the plane at right-angles to the dipoles remains unchanged.

In the case of an array with two dipoles in each row the diagram will be modified by multiplying by:

$$\frac{\cos\left(\frac{\pi}{2} \sin \theta + \frac{\varphi}{2}\right)}{\cos\left(\frac{\pi}{2} \sin \theta\right)}$$

In the case of an array with four dipoles in each row, the diagram will be modified by multiplying by:

$$\frac{\cos\left(\pi \sin \theta + \frac{\varphi}{2}\right)}{\cos(\pi \sin \theta)}$$

where φ is the phase difference between the currents in the two halves of the array. The approximate angle of slew, in terms of the phase difference between the two halves of the array is:

$$\sin^{-1} \frac{\varphi}{\pi} \text{ for the array two dipoles wide}$$

$$\sin^{-1} \frac{\varphi}{2\pi} \text{ for the array four dipoles wide}$$

It is inadvisable to slew the main lobe more than approximately 15° , as large side lobes will otherwise form which may cause interference outside the service area.

5. *Ground conductivity.*

In many cases, the conductivity of the ground is such that the efficiency and the diagram may be degraded if an earth mat is not placed under the array. This earth mat should consist of a number of parallel wires, spaced 0.1λ apart and run parallel to the dipoles. The length of the wires and the number of wires should be such that the earth mat extends $\frac{\lambda}{2}$ beyond the extremities of the array when viewed in plan.

- (a) Diagram in the vertical plane parallel to the dipole
- (b) Diagram in the plane at right-angles to the dipole

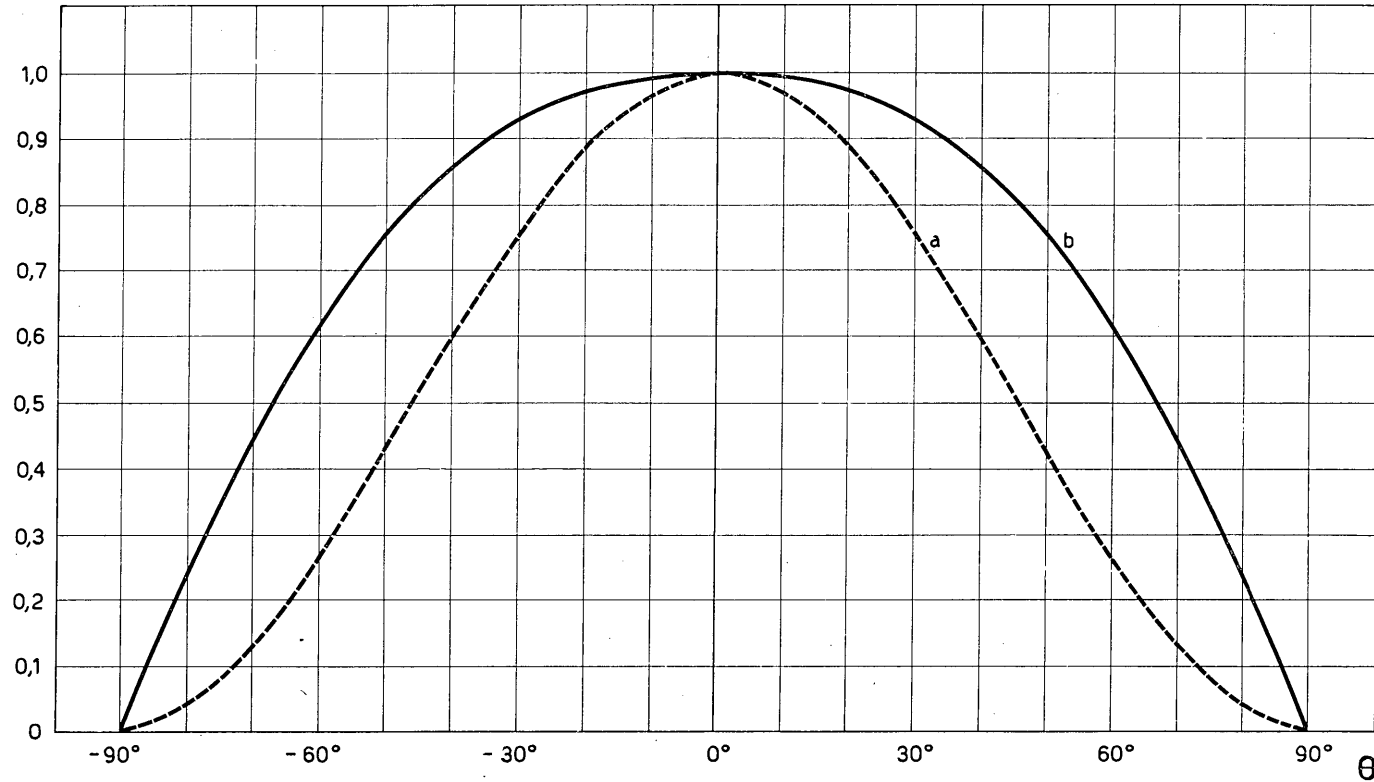
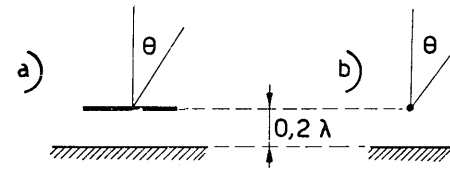


FIGURE 1

Diagram of a single $\frac{\lambda}{2}$ horizontal dipole

(a) Diagram in the vertical plane parallel to the dipoles

(b) Diagram in the plane at right-angles to the dipoles

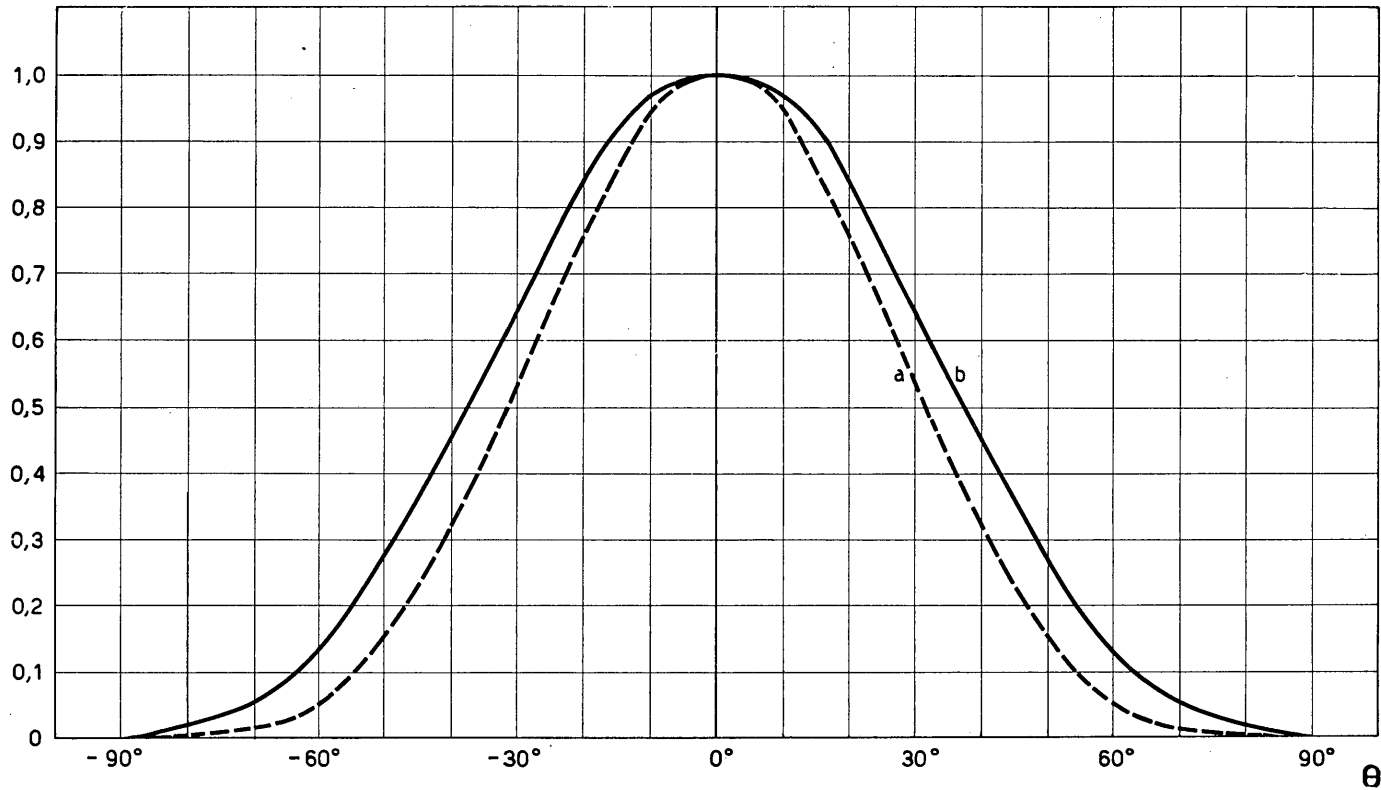
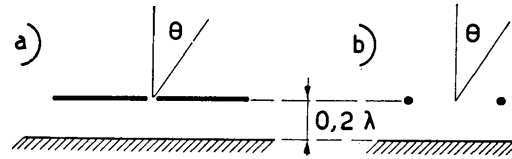


FIGURE 2

Diagram of an H2/2 array on its back

- (a) Diagram in the vertical plane parallel to the dipoles
- (b) Diagram in the plane at right-angles to the dipoles

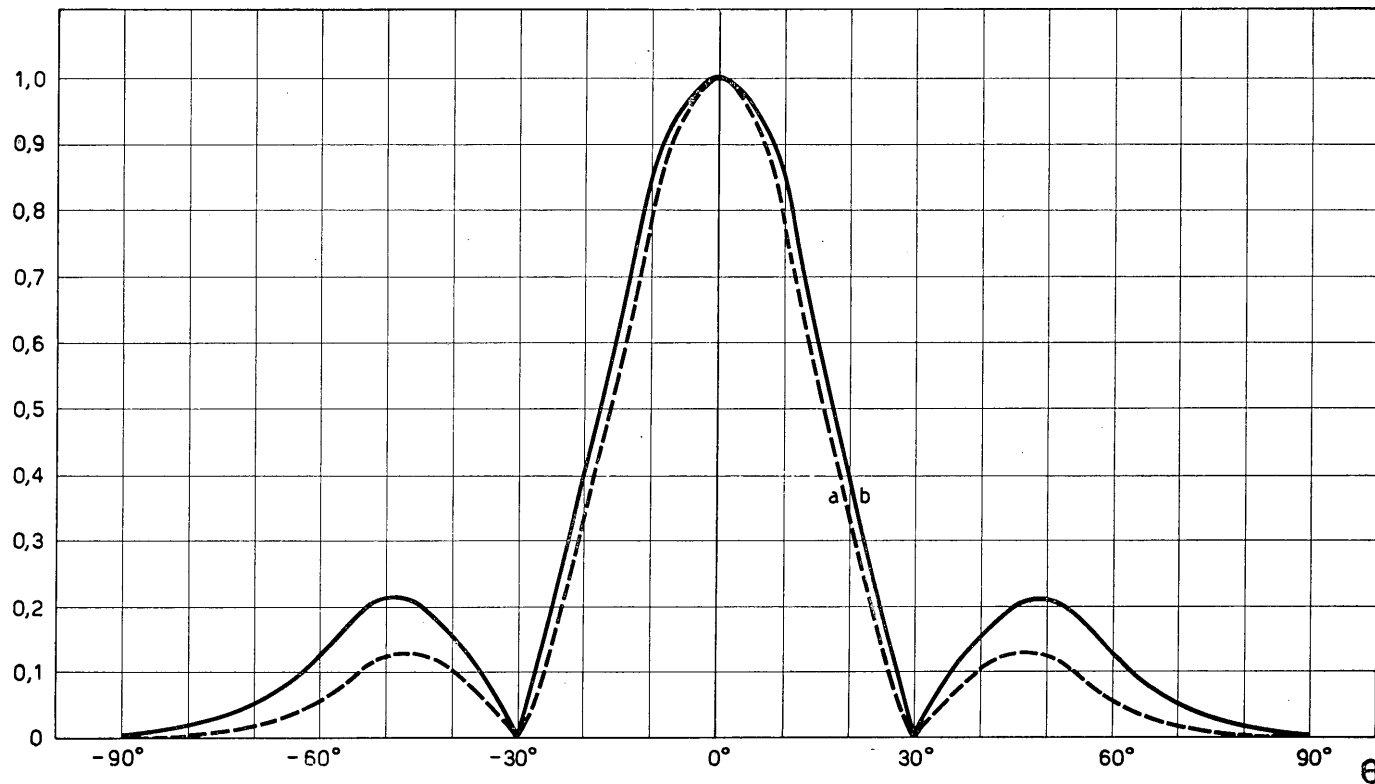
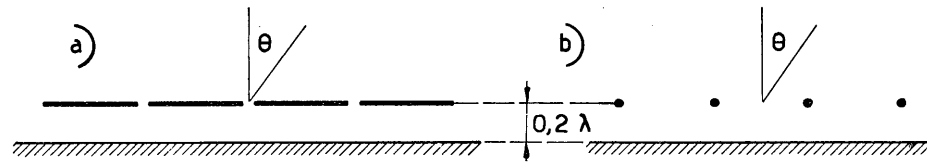


FIGURE 3

Diagram of an $H4/4$ array on its back



REPORT No. 87 *

**DESIGN OF TRANSMITTING ANTENNAE
FOR TROPICAL BROADCASTING****Complement to Report No. 86**

(Question No. 156 (XII))

(Warsaw, 1956)

1. Doc. No. 470 (Warsaw) from the United Kingdom describes briefly the measurements carried out in Barbados of short-wave (decametric) broadcast transmissions from Trinidad (350 km) on 3 and 6 Mc/s and the attempts made to observe the field intensities of transmissions from Jamaica.
 2. Consideration of the data indicates that a vertical incidence 4-element aerial $1/4$ -wavelength above ground will be useful for minimizing low-angle radiation beyond a service area limited to about 350 km and thus reduce the value of received signal level. For greater distances such an antenna will not provide as high a desired field as a simple dipole, especially one with a height approaching half a wavelength above ground.
 3. It is considered that further studies should be undertaken to collect data on antennae which will enable radiation to be maintained at the necessary angle of elevation to provide a service at distances of the order of 800 km, while, at the same time, minimizing radiation at lower angles of elevation.
 4. It is also desirable that whilst communicating data on frequency requirements, administrations should define the area for which the broadcast service is intended.
-

REPORT No. 89 **

INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING

(Question No. 102 (XII) and Study Programme No. 113 (XII))

(Warsaw, 1956)

This Report summarizes the results of the studies, contained in Warsaw Docs. Nos. 231, 356 and 553, that were carried out to determine by subjective tests the ratios of wanted-to-unwanted signal required to satisfy various percentages of broadcast listeners. It also summarizes the views expressed in the Study Group meetings at Warsaw.

* This Report was adopted unanimously.

** This Report was adopted unanimously. See also Report No. 127.

Doc. No. 356 (India) gives the results of an extensive series of subjective tests carried out under conditions which, it is claimed, generally simulate those of actual domestic broadcasting listening in the absence of fading. A broadcast receiver with a substantially flat response up to about 4 kc/s but with a filter giving an attenuation of about 8 db at 5 kc/s and a sharp cut-off above this frequency was used.

For unwanted signals of A2 and A3 classes of emission and for various frequency separations between the carriers of the wanted and unwanted signals, listeners were presented with various ratios of wanted-to-unwanted signal in random order and asked to state whether they considered the reception satisfactory or unsatisfactory. The curves given in the Annex show, the wanted-to-unwanted signal ratios required to provide 90%, 70% and 50% listener satisfaction for unwanted signals of A2, A3 telephony and A3 broadcasting classes of emission and for various frequency separations up to 5 kc/s.

Table I gives the same information for:

- (a) frequency separations of 0 kc/s and 5 kc/s exactly;
- (b) nominal frequency separations of 0 kc/s and 5 kc/s under the most unfavourable conditions that could arise within the maximum permissible frequency tolerances of both wanted and unwanted signal as specified in the Radio Regulations, (Atlantic City 1947).

Doc. No. 231 (United Kingdom) gives details of the results of subjective tests made to determine the ratio of wanted-to-unwanted signal as a function of the frequency separation of the carriers of the two signals. Two typical broadcast receivers were used having a fairly uniform response up to about 4 kc/s falling to about —8 db to —10 db at 5 kc/s. The unwanted signal was modulated by speech with a frequency range limited to 3 kc/s. The ratio necessary to satisfy nearly all listeners varied from about 54 db at 1 kc/s separation to a maximum of 56 db between 2 and 3 kc/s separation, falling to 52 db at 5 kc/s separation. The corresponding ratios when nearly all the listeners found the conditions unsatisfactory were about 15 db lower. Subsequent tests to determine the ratio at which interference was “perceptible” gave intermediate values.

Doc. No. 553 (Federal German Republic) gives the results of similar tests made with two types of receiver, one a narrow-band receiver with considerable attenuation above 3 kc/s and the other a wider-band receiver with an attenuation of about 8 db at 5 kc/s. For the wide-band receiver, as commonly used for broadcast listening, the wanted-to-unwanted signal ratio for various frequency separations follows the same general curve as before and at a frequency separation of 5 kc/s is 43 db for 90% listener satisfaction.

Comparison of the results arrived at in the three documents show that there is a considerable degree of agreement. The values are within ± 5 db and those in the United Kingdom and Federal German Republic documents bracket those in the Indian document. There is therefore sufficient justification to assume that the values of the wanted-to-unwanted signal to provide the various degrees of listener satisfaction given in Table I and the annexed curves are reliable.

From an examination of Table I, it will be seen that when the unwanted signal is a mobile A3 emission, there is a considerable increase in the required wanted-to-unwanted signal ratio when allowance is made for maximum frequency tolerances. The possibility of interference to broadcasting services from mobile services would be appreciably reduced, particularly where the two services have the same nominal frequency, if the mobile services operated within closer frequency tolerance, if possible with the same tolerance as the fixed and broadcasting services.

Although the sidebands of the unwanted signal contributed to some extent to the interference, the heterodyne beat note between the carriers of the wanted and unwanted signal was always predominant. This was the case for a frequency separation of 5 kc/s between the two signals and although the receivers used provided an attenuation of some 8–10 db to the beat note, the use of a filter to provide further attenuation would have reduced the required wanted-to-unwanted signal ratio. Further studies are needed to ascertain what additional attenuation at 5 kc/s could

usefully be provided and what would then be the required wanted-to-unwanted signal ratio. For this purpose consideration should also be given to the possibilities of providing suitable filters in new and existing receivers.

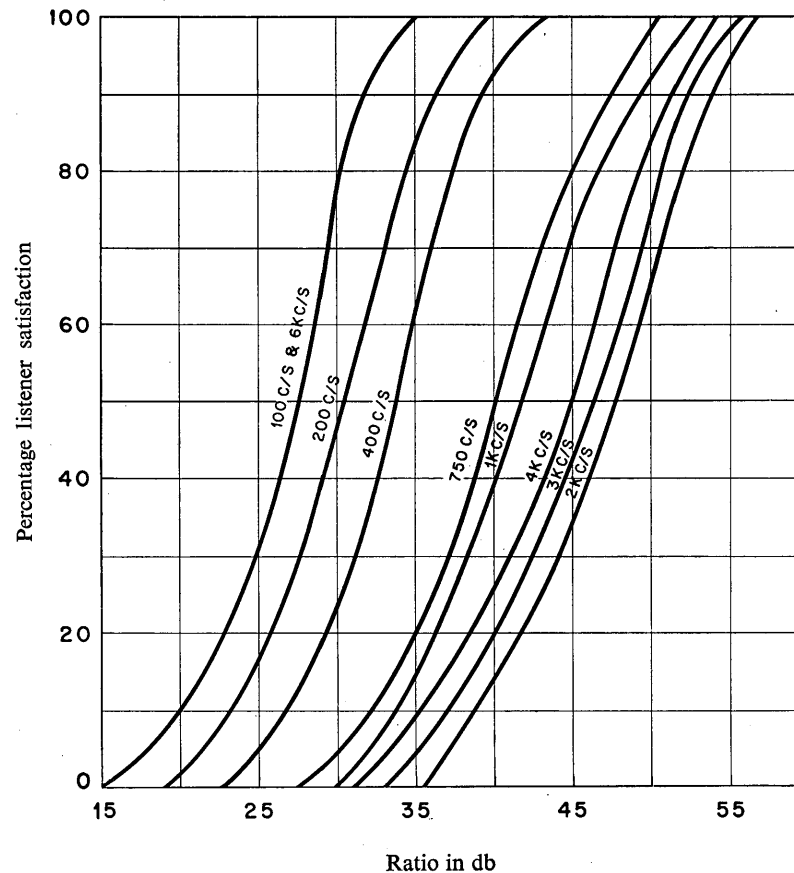
It is agreed that since the figures shown in Table I are derived from measurements made under steady-state conditions, appropriate allowance should be made for fading when using these figures to derive the protection ratios to be used in practice. The value of fading allowance to be used for tropical broadcasting requires further study.

India wishes to record her opinion that protection ratios should be based on those figures in Table I that provide 90% listener satisfaction and that the figures for 70% and 50% are for information only and should not be regarded as the lower limits of acceptability. Australia and South Africa and the French Oversea Territories are of the opinion that a listener satisfaction higher than 50% should be provided. South Africa and Australia consider it would be impracticable to achieve 90% listener-satisfaction from the aspect of signal-to-noise ratio, particularly under heavy static conditions, and therefore to aim to achieve about 80% listener-satisfaction for signal-to-interference would be more realistic. The United Kingdom is of the opinion that the wanted-to-unwanted signal ratios given in Table I are based on too critical an assessment and that lower figures would be generally acceptable. The United Kingdom is also of the opinion that from practical considerations, protection ratios will have to be based on figures providing about 50–70% listener satisfaction.

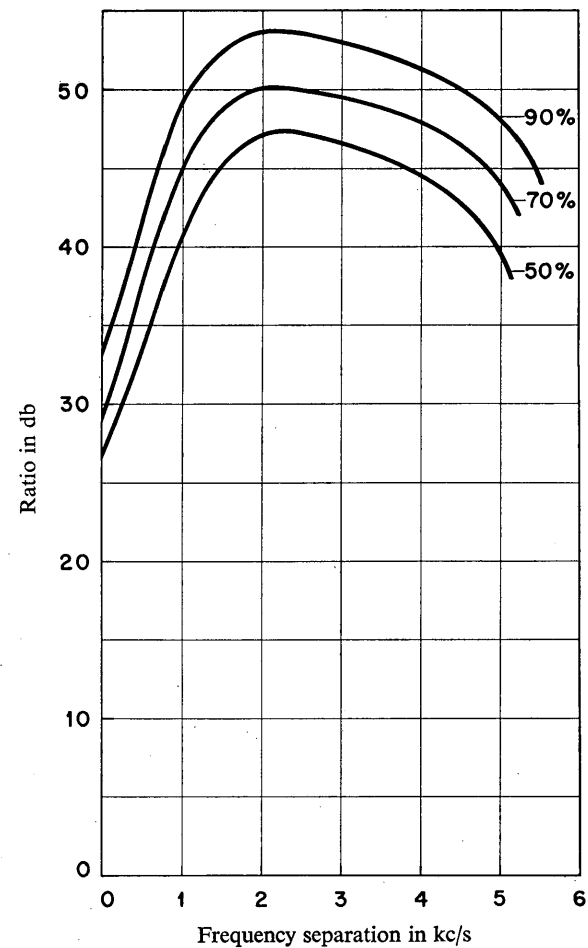
TABLE I

Interfering emission	Maximum frequency tolerance (Rad. Regs.) (c/s)	Frequency separation (kc/s)	Signal/interference ratios for 90%, 70% and 50% listener satisfaction (db)					
			Ignoring frequency tolerances			Allowing for maximum frequency tolerances		
			90 %	70 %	50 %	90 %	70 %	50 %
A2 — fixed (525 c/s tone)	150	0	35	31	28	42	38	34
A2 — mobile (525 c/s tone)	1000	0	35	31	28	49	45	42
A3 — fixed (3 kc/s max. modulation)	150	0	33	30	28	40	36	33
A3 — mobile (3 kc/s max. modulation)	1000	0	33	30	28	50	47	44
A3 — broadcasting	150	0	33	30	28	44	40	36
A2 — fixed (525 c/s tone)	150	5	39	37	36	43	40	38
A2 — mobile (525 c/s tone)	1000	5	39	37	36	49	46	43
A3 — fixed (3 kc/s max. modulation)	150	5	48	44	40	50	46	42
A3 — mobile (3 kc/s max. modulation)	1000	5	48	44	40	52	48	45
A3 — broadcasting	150	5	48	46	44	49	46	44





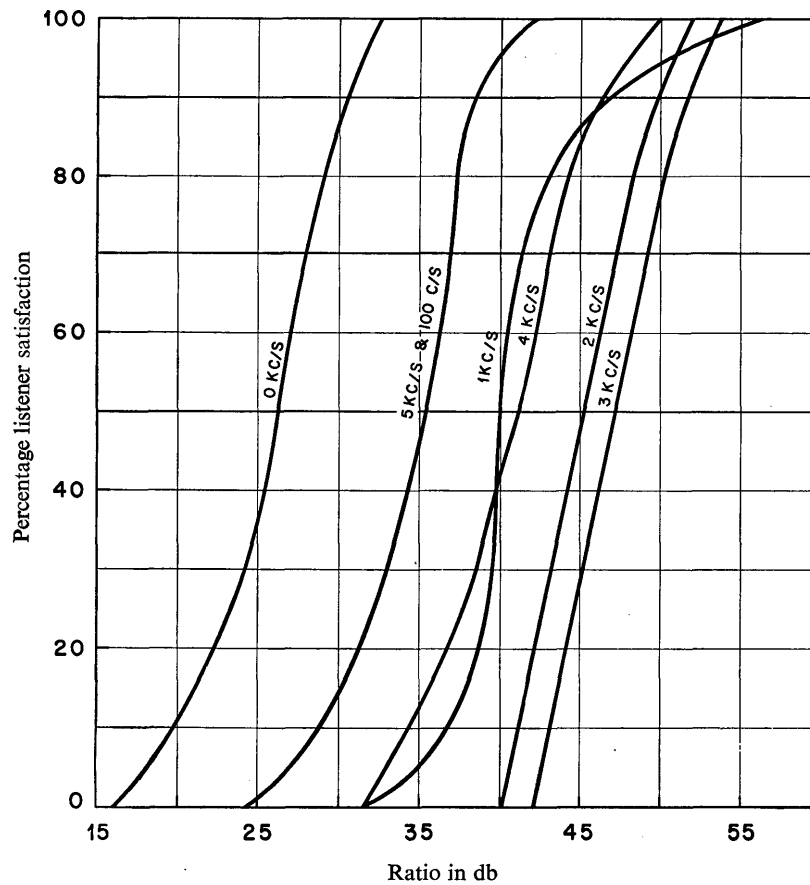
(a) Main programme: speech
Interference: A2 telegraphy



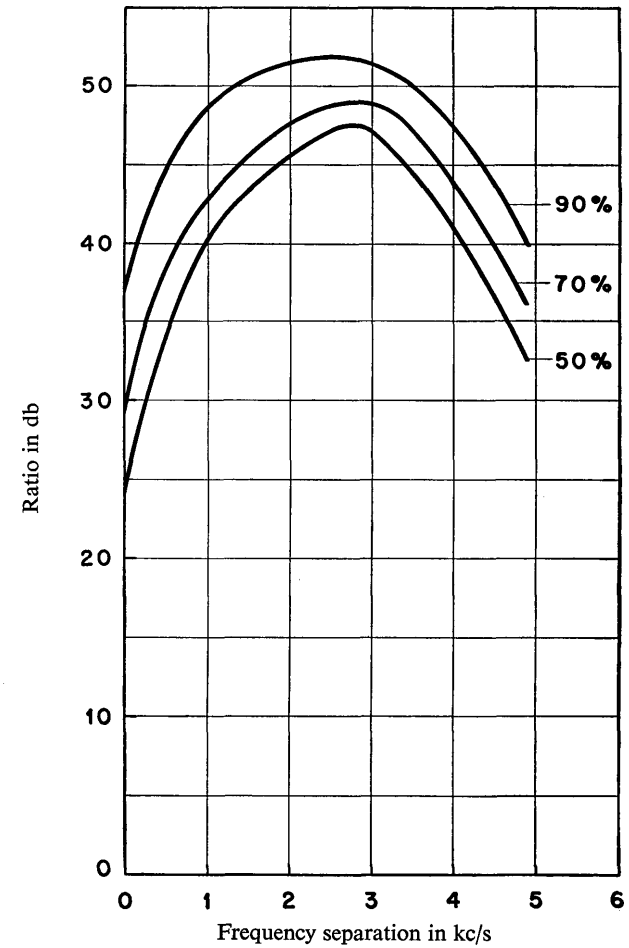
(b) Ratio of wanted to unwanted signal for 90%,
70% and 50% satisfaction

FIGURE 1

Wanted to unwanted signal ratio required against interference from A2 telegraphy



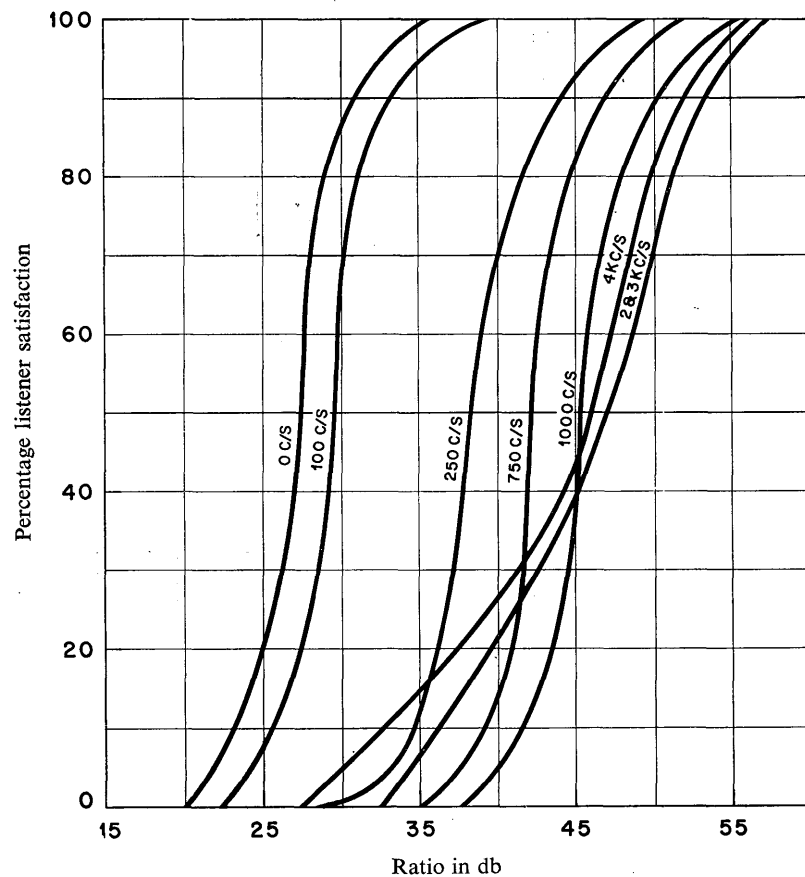
(a) Main programme: speech
Interference: A3 telephony



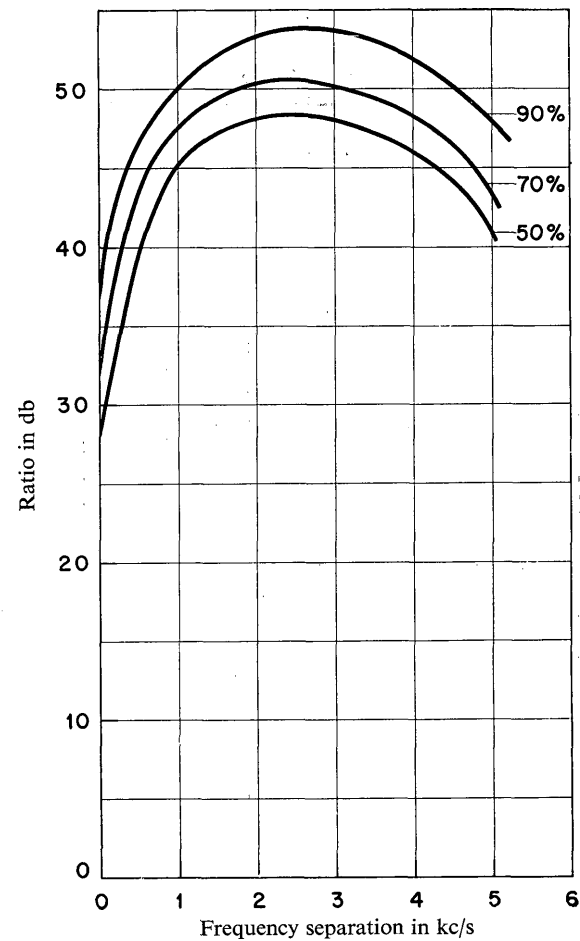
(b) Ratio of wanted to unwanted signal for 90%,
70% and 50% satisfaction

FIGURE 2

Wanted to unwanted signal ratio required against interference from A3 telephony



(a) Main programme: speech
Interference: A3 broadcasting (music)



(b) Ratio of wanted to unwanted signal for 90%,
70% and 50% satisfaction

FIGURE 3

Wanted to unwanted signal ratio required against interference from broadcast transmission

REPORT No. 116 *

MEASUREMENT OF WOW AND FLUTTER IN EQUIPMENT
FOR SOUND RECORDING AND REPRODUCTION

(Study Programme No. 161 (X))

(Warsaw, 1956 — Los Angeles, 1959)

Consideration of Docs. X/3 (Germany), X/15 (Japan), X/22 (USSR) and 214 (Japan) of Los Angeles, 1959, showed that it was still premature to standardize measurement of wow and flutter or the weighting curve to be used in these measurements.

Until a recommendation could be made, it was found desirable:

1. that, when values of wow and flutter are given, it should always be stated whether r.m.s., mean or peak values are used, the weighting curve used, if any, and the form of this curve;
2. that, when measuring wow and flutter for magnetic tape machines, it should be noted that the recorder used for recording the test tape, or the reproducer used for replaying the tape recorded on the machine to be tested, should themselves have wow and flutter values which are as small as possible. If known, these values should be stated.

For information, two weighting curves for the measurement of wow and flutter are given in Fig. 1, one used in Japan in connection with measurements of r.m.s. values, the other proposed in connection with measurement of peak values in Doc. X/3 (Federal German Republic) of Los Angeles, 1959.

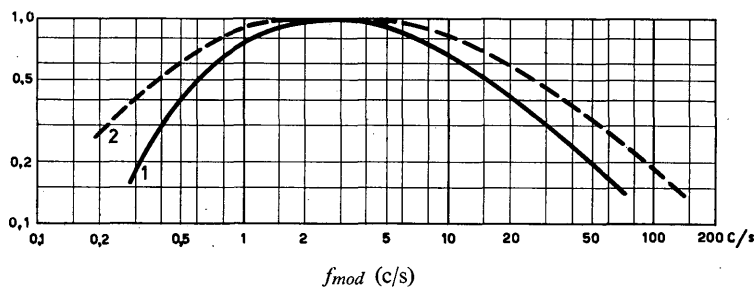


FIGURE 1

1. *Weighting curve as proposed in Document X/3 (Federal German Republic)*
2. *Weighting curve as used in measurement referred to in Document X/15 (Japan)*

* This Report which replaces Report No. 78, was adopted unanimously.

REPORT No. 117 *

MEASUREMENT OF PROGRAMME LEVEL IN SOUND BROADCASTING

(Question No. 151 (X))

(London, 1953 — Los Angeles, 1959)

Report No. 33 states that two different types of level indicators are in general use, one essentially a peak indicating instrument, the other a mean value indicating instrument (VU-meter).

The discussion [at the IXth Plenary Assembly on Docs. Nos. X/15 (Federal German Republic) and X/17 (France) of Los Angeles, 1959, showed that broadcasting organizations were not prepared to replace their existing instruments, due to the difficulties this would cause in programme production. Thus, it does not seem possible to reach agreement on a recommendation giving specifications for one or even both of the two types mentioned in Report No. 33.

The discussion, also revealed that research was in progress and that new information would be submitted to the C.C.I.R. before the next Plenary Assembly. It was therefore found desirable to retain Question No. 151 (X) and Study Programme No. 109 (X).

In order to collect all possible information concerning the use of programme level indicators before the date of the Xth C.C.I.R. Plenary Assembly, a further investigation of the various types of instruments in use is considered advisable.

REPORT No. 118 **

HIGH FREQUENCY BROADCASTING

Justification for the use of more than one frequency per programme.

(Question No. 37)

(Study Group No. X)

(Geneva, 1951 — Warsaw, 1956 — Los Angeles, 1959)

The C.C.I.R. has studied the technical data contained in Doc. No. 635 of Mexico, and agrees that it is essential to secure the greatest possible economy in the use of radio frequencies and that to this end, as a general rule, only one frequency should be used for the transmission of one programme to one reception area. It is, however, of the opinion that technical conditions do exist at certain times and over certain paths which would justify the use of more than one transmission frequency to assure the continuous reception of one programme in one reception area (i.e. the area to which the programme is directed).

* This Report was adopted unanimously.

** This Report, which replaces Report No. 76 was adopted unanimously.

Wave propagation conditions over certain paths (e.g. very long paths or paths passing through the auroral zones) may be difficult to forecast, or the rate of change of FOT may be high (e.g. at sunrise or sunset). Listeners to broadcasting cannot advise the transmitter of an unexpected deterioration in reception conditions as may be the case in radio services other than broadcasting.

The existence of these conditions could justify the simultaneous use of more than one frequency, each in a different band, to cover such periods and paths. In addition there may be cases where the depth of the area extending outward from the transmitter is too great to be served by a single frequency and more than one frequency may be needed.

The use of directional antennae is essential in most cases to ensure a satisfactory signal-to-noise ratio, as recommended by the Mexico City High Frequency Broadcasting Conference, and this limits the geographical area covered by each transmitter and its associated antenna to an extent differing with each particular case. Because of this, it may be necessary to use more than one transmitter and associated antenna to cover a given reception area. By synchronizing transmitters, the number of frequencies in the same band may be reduced to two and, under favourable conditions, to one (Recommendation No. 205).

The angle subtended by the reception area at the transmitter, its mean distance from the transmitter and its depth, may differ greatly from one case to another. This limits the value of adopting defined geometric reception areas as it would give rise to insufficient coverage in some cases and a wasteful use of frequencies in others.

Doc. X/13 (Czechoslovakia) of Los Angeles, 1959, gives a detailed solution to the problem of broadcasting to particular areas of unusual shapes. It is clear that the choice of antennae and frequencies as well as their number can only be made as the result of a careful study of the conditions of propagation from the transmitter to all parts of the area concerned.

No general rules are likely to be effective and each problem should be examined separately. This is therefore the final Report on Question No. 37*.



REPORT No. 119 **

HIGH-FREQUENCY BROADCASTING RECEPTION

(Question No. 39 (X))

(Geneva, 1951 — Los Angeles, 1959)

This report has been prepared utilizing the available results of past research regarding the short and long term variability of high-frequency broadcasting signals, atmospheric noise and industrial noise intensities, together with the results of subjective tests of the acceptable ratios of steady desired-to-undesired signals and of steady signal-to-atmospheric and industrial noises.

Although it is believed that further theoretical and empirical work should be carried out in this field, it is felt that available material makes it possible to supplement provisionally the existing information and to estimate allowances which should be made to take into account the short and long term variability of signal and atmospheric noise intensities in order to provide acceptable service for any specified percentage of the time.

* Question No. 37, and Study Programmes Nos. 107 and 108 are deleted.

** This Report, which replaces Report No. 14, was adopted unanimously.

The table sets forth, for purposes of information, the fading safety factors which are necessary to assure a specified signal-to-interference ratio for particular percentages of the time *.

Consideration has not been given to the allowances to be made when there is more than one interfering signal or a combination of interfering signals and noise. This is known to be an exceedingly complex problem, and, although some theoretical investigations have been performed, there is no available information on the subjective aspect involved.

	1	2	3	4
Desired signal to undesired signal (db)	10	13	23	16
Desired signal to atmospheric noise (db)	6	16	22	17
Desired signal to industrial noise (db)	6	10	16	12

Column 1: The short-term fading allowance which must be made to ensure that the steady state ratio is achieved for 90% of any given hour.

Column 2: The long-term fading allowance which must be made to ensure that the steady state ratio is achieved for 90% of the hours in any one month at a particular time of day in 90% of the cases.

Column 3: The sum of the values in Columns 1 and 2, is the overall variability allowance which must be made to ensure that the steady state ratio is achieved for 90% of any hour in 90% of the hours in any month at a particular time of day and in 90% of the cases. This represents an assured steady state ratio for 96% of the overall time.

Column 4: The square root of the sum of the squares of the values given in db in Columns 1 and 2, is the overall variability allowance which must be made to ensure that the steady state ratio is achieved for 90% of the overall time.

The figures in the table relating to the time availability of service were selected on a theoretical basis and on experience derived principally from medium-wave broadcasting. Some doubt exists as to the practicability of achieving these percentages, since recent calculations of the transmitter power required to provide this time availability at the present accepted steady state conditions have produced quite unrealistic results.

Between Geneva, 1951 and Los Angeles, 1959, however, no further documents were submitted on this question, and there seems little hope of further progress while Question No. 39 retains its general wide scope. This should therefore be considered the final Report on this question.

It is probable that more will be achieved by confining studies to specific problems for which new questions will be formulated.

** Refer to Doc. 43 and 66 of Washington and Doc. Nos. 160, 178 and 215 of Geneva, 1951.

REPORT No. 120 *

DETERMINATION OF NOISE LEVEL FOR TROPICAL BROADCASTING

(Question No. 155 (XII))

(Warsaw, 1956 — Los Angeles, 1959)

Question No. 155 (XII) calls for a comprehensive study of the characteristics of atmospheric noise in tropical broadcasting areas, and for its measurement by both objective and subjective methods.

Doc. No. 92 (India) of Los Angeles, 1959, entitled "Determination of noise level for tropical broadcasting" reports measurements of atmospheric noise made at Delhi, using an experimental arrangement, which is essentially an adaptation of that used in the Thomas method.

FIGURE 1 (*Winter*)

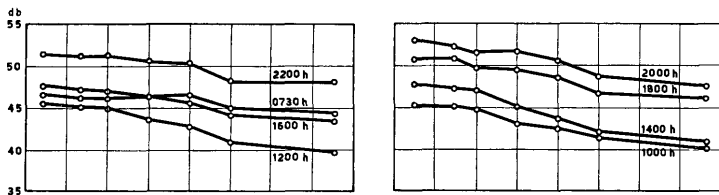


FIGURE 2 (*Equinox*)

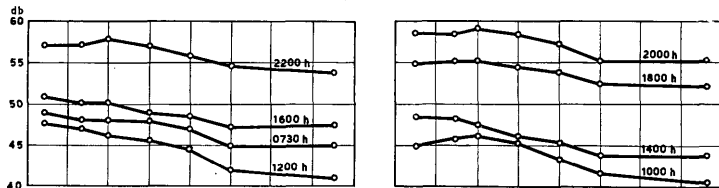
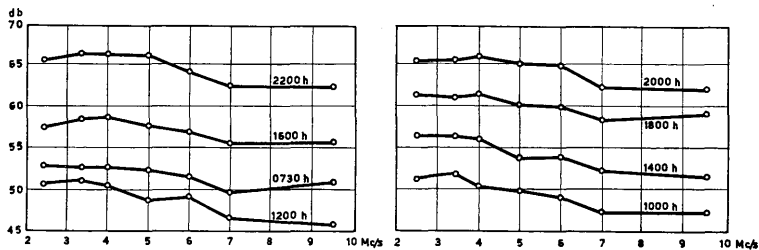


FIGURE 3 (*Summer*)



Minimum signal required for satisfactory listening (db rel. 1 μ V/m)

* This Report was adopted unanimously.

The methods adopted for objective and subjective measurements are described and correlation between the two sets of measurements is attempted. An analysis of the data showing seasonal and frequency variations is made and correlation with the sunspot numbers is being attempted. It is concluded on the basis of the analysis of measurements so far carried out that 40 db protection over the prevailing noise is required for average satisfactory listening for 90% of the time, irrespective of the frequency of operation and the time of the day corresponding to listener satisfaction of 50% and/or a steady signal.

Figs. 1, 2 and 3 show the variation of the subjective values of minimum satisfactory signal at various frequencies and time of day for the different seasons.

REPORT No. 121 *

FADING ALLOWANCES FOR TROPICAL BROADCASTING

(Question No. 157 (XII))

(Warsaw, 1956 — Los Angeles, 1959)

Question No. 157 (XII) calls for a study of the characteristics of fading in tropical zones and the allowances for fading that should be made in planning tropical broadcasting services.

Two contributions to this question were received at Los Angeles, and are summarized below:

1. Document XII/8 of Los Angeles, 1959 (*Preliminary Report on the Statistical Analysis of Fading on Short-wave Transmission*).

This contribution from India describes experiments for fading measurements conducted at oblique incidence with continuous wave, voice modulated broadcast transmissions on 4.7 Mc/s, 9 Mc/s and 15 Mc/s as well as on pulse transmissions on the equivalent vertical incidence frequency. The theoretical considerations and the experimental set-up used in the measurements are described and an analysis of the data collected is given. Based on the analysis of the data, the following conclusions are drawn:

1.1 The distributions observed from the analysis of a few typical random fading curves are found to be Rayleigh, [normal or log-normal and this finding is in keeping with similar observations elsewhere.

1.2 On short waves, no correlation or similarity has been observed between the amplitude distributions for the simultaneously recorded fading records of:

- an oblique incidence C.W. transmission and
- a pulsed reflection on the equivalent vertical incidence frequency transmission, both taken at the same spot.

A possible explanation for this conclusion is lack of similarity or correlation between the region of reflection of the vertical incidence pulse signal and that of the oblique incidence C.W. signal, owing to the large distances separating them.

* This Report was adopted unanimously.

2. Document XII/5 of Los Angeles, 1959 (*Fading allowances for tropical broadcasting transmissions*).

This contribution by the United Kingdom describes a method of measurement developed for investigating the nature, type and intensity of fading of broadcast transmissions under tropical conditions. Recordings of fading signals are made on magnetic tape in tropical areas and are analysed later in the United Kingdom. The paper presents an analysis of recordings made in three tropical broadcasting areas at different times of the day and at various distances from the transmitter.

The method of measurement employs a receiver connected to a suitable antenna having preferably the same orientation as the polarization of transmission being measured. The receiver which operates linearly over the fading range is tuned to the transmission with the beat frequency oscillator on, the automatic gain control off and the selectivity set to a narrow bandwidth. The output is fed to a good tape recorder which has a calibration signal covering a range of 20 db in 4 db steps.

The recordings are analysed in the United Kingdom by means of a level distribution analyser.

For three areas, namely Barbados and Trinidad, Ghana and Singapore, the recordings have been analysed and a mean level distribution curve obtained for each case covering the periods before and after 1800 hours local time.

The results showed little dependence on location of transmitters or time of the day. However, they appeared to show some small dependence on range and have therefore been grouped under three ranges, 0–100 km, 100–350 km and over 350 km.

The fading experienced in the 100–350 km range is somewhat less than for the other two ranges. This has been attributed as possibly due to interaction between ground and one-hop sky wave in the case of 0–100 km and multipath sky wave propagation in the case of over 300 km groups.

The results appear in general to conform fairly closely to the Rayleigh type of distribution. The records show evidence of phase interference between ground and sky wave at very short distances, giving rise to a more or less regular beat pattern with a period of 15–20 seconds. Another feature noticed is the increased rate of fading experienced after local sunset.

REPORT No. 122 *

ADVANTAGES TO BE OBTAINED BY USING ORTHOGONAL WAVE POLARIZATIONS IN THE PLANNING OF BROADCASTING SERVICES IN THE VHF (METRIC) AND UHF (DECIMETRIC) BANDS

Television and sound

(Question No. 101)

(Study Group No. XI)

(Warsaw, 1956 — Los Angeles, 1959)

Investigations have been conducted in several countries to ascertain the advantages which can be obtained in sound and television broadcasting by using polarization discrimination in reception. The results of extensive studies made in Europe by the Federal German Republic,

* This Report which replaces Report No. 85, was adopted unanimously.



France, Italy and the United Kingdom and also in the United States of America, have been made available in documents at Warsaw (1956) and Geneva (1958); and a reasonably definite answer may now be given to the question.

1. VHF (metric) band.

In this band of frequencies between 30 and 300 Mc/s, the median value of discrimination that can be achieved at domestic receiving sites by the use of orthogonal polarization may be as much as 18 db, and under these conditions, the values exceeded at 90% and 10% of the receiving sites are about 10 db and 25 db respectively.

The values of discrimination are likely to be better in open country and worse in built-up areas or places where the receiving antenna is surrounded by obstacles. For domestic installations in densely populated districts the median values of 18 db will usually only be realized at roof level; and this value may be reduced to 13 db or less at street level.

No significant changes in the polarization of metric waves due to transmission through the troposphere have been observed over distances exceeding 200 km. Furthermore, there have been no reports of systematic changes in polarization effects with frequency in the metric band, not with distance nor type of terrain.

It must be emphasised, however, that in order to realize the discrimination ratios mentioned above, certain precautions are necessary at both the transmitting and receiving installations; cases have been reported in which for a transmitter of horizontally polarized waves, some 7% of the radiated power was vertically polarized. It is clear that if the best discrimination is to be obtained for co-channel operation, the transmitters and antenna systems must be designed and installed so as to radiate as much as possible of the total power on the assigned polarization.

In the same way, in order to achieve the desired discrimination at the home receiving installation, the reception of the undesired orthogonally polarized waves on the antenna feeder and on the receiver itself must be reduced to the minimum practicable value.

2. UHF (decimetric) band.

Experiments have been conducted in the United Kingdom using horizontally polarized radiation on a frequency of about 500 Mc/s. Systematic measurements were made to determine the polarization discrimination at typical urban and rural sites at distances up to about 55 km from the transmitter. The results showed that the discrimination obtained is similar to that already described above for frequencies in the VHF band, although the factor exceeded for 90% of the receiving sites was only 8 db (as compared with 10 db for VHF). It is to be noted, however, that the transmitting antenna in use had considerable directivity, and there was a marked decrease in the polarization discrimination for directions of reception some 40° away from the direction of maximum radiation.

As in the VHF band, care is necessary to ensure that the transmitter and receiver respectively do not emit or receive radiation of the undesired polarization. Apart from this, however, experience indicates that in the UHF band, the use of horizontal polarization offers advantages, because of the greater directivity obtainable at the receiving antennae; this reduces the effect of reflected waves, particularly in town areas. The European Broadcasting Union, therefore, considers that frequency assignments in these bands should be based on the general use of horizontal polarization, though exceptions may be made in cases where orthogonal polarization is necessary to achieve the desired protection.

3. Conclusion.

From the studies described above, it is clear that the use of orthogonal polarization for broadcasting stations operating in the same frequency channel is of material assistance in discriminating against the reception of undesired signals. Worth-while advantages are obtainable over the whole band of frequencies from 40 to 500 Mc/s and within the normal broadcasting service ranges.

From the uniformity of the discrimination obtained over these frequencies, it is considered to be almost certain that the advantages will extend to the top of the UHF broadcasting band at nearly 1000 Mc/s.

This Report is considered to provide a sufficient answer to Question No. 101 for practical use, and this question should now be concluded.

BIBLIOGRAPHY

Docs. Nos. 267, 435 and 512 (Warsaw, 1956).

Docs. Nos. V/1, V/6, V/12, V/23 and V/27 (Geneva, 1958).

REPORT No. 123 *

TELEVISION STANDARDS FOR BANDS IV AND V

(Question No. 118 (XI))

(Los Angeles, 1959)

1. Introduction.

At the VIIIth Plenary Assembly of the C.C.I.R. it was concluded that further study, development and testing, were required before the necessary consideration could be given to the question of television standards for Bands IV and V.

The advantage of reaching agreement on common standards for the higher bands was fully appreciated, and the Director of the C.C.I.R. sought assurances from Administrations in Europe that, if they found it necessary to use these bands to provide a public television service before the question of standards had been answered, such Administrations would not prejudice the future planning of the two bands. This was generally agreed.

2. The Moscow Meeting.

In accepting unanimously at Warsaw the invitation of the U.S.R.R. to hold an interim meeting of Study Group XI in Moscow in 1958, it was hoped that the studies and tests then in hand, or being started, by many Administrations would enable recommendations to be made at Moscow. It was apparent at Moscow, however, that although the work was nearing its final phase, more remained to be done before some Administrations were able to reach conclusions.

Although there was no urgency at that stage to decide on standards for a colour television system for Bands IV and V, an early decision was required on those aspects of the monochrome standards which have an important bearing on the frequency planning of the bands. This was so because of the need of some countries to set up monochrome services in Band IV, while the requirements for future television services in Bands IV and V would be needed at the Ordinary Administrative Radio Conference, Geneva, August 1959 and at the next VHF/UHF European

* This Report was adopted unanimously.

Broadcasting Conference. The point was also made that the use of a common monochrome standard in Bands IV and V, which would permit the later introduction of a colour system compatible with that standard, would aid frequency planning.

In the light of all these considerations it was agreed that every endeavour should be made to complete the work then in progress by the various Administrations and for these Administrations to submit their conclusions to the C.C.I.R. as soon as possible. It was hoped that in this way sound recommendations based on all the available information could be made at the IXth Plenary Assembly.

3. Important Aspects of the Problem.

The attention of Administrations taking part in the studies concerned with monochrome standards was drawn to the following main aspects of the problem:

- definition standards, i.e. number of lines per picture;
- channel bandwidth;
- location of vision and sound carriers within the channel.

At the Moscow meeting it was stated that those Administrations using 625 lines in Bands I and III wished to retain this definition for operation in Bands IV and V. Of the European Administrations using other than 625-line definition in the lower bands, the French Administration wished to retain 819-line definition in Bands IV and V, while other Administrations concerned were considering whether they would wish to use the standards used in Bands I and III in Bands IV and V or different standards.

With regard to bandwidth, it was stressed that frequency planning would be facilitated if it were possible to use a standard channel spacing throughout Europe. With this end in view, some Administrations employing a 7 Mc/s channel for their 625-line systems stated that, in the general interest, they would consider using an 8 Mc/s channel spacing in Bands IV and V if this would enable a common standard to be achieved.

Most Administrations using 625-line definition would wish to retain their existing spacing of vision and sound carriers but would agree to use coincident vision carriers.

No European Administration was ready to take a decision on the form of colour system eventually to be used. However, as several Administrations were experimenting with colour systems using a colour sub-carrier within the luminance band, and as there would be considerable advantage in frequency planning if agreement could be reached on the location of this sub-carrier within the channel, it was suggested that those Administrations doing experimental work on 625-line systems should consider the use of a colour sub-carrier frequency of 4.43 Mc/s approximately.

4. Conclusions of the Moscow Meeting of Study Group XI.

4.1 Administrations were requested to expedite their studies in connection with:

- definition standards
- channel bandwidth
- location of the vision and sound carriers within the channel,

for the monochrome systems to be used in Bands IV and V. They were asked to submit their reports and conclusions to the C.C.I.R. by *1st January, 1959*, thereby enabling firm recommendations to be formulated at the IXth Plenary Assembly.

4.2 It was recommended that those Administrations proposing to use 625-line systems in Bands IV and V should study the use of a colour sub-carrier of approximately 4.43 Mc/s in their experimental work on colour television.

5. Statements submitted by Administrations.

Since the Meeting of Study Group XI in Moscow the following statement have been submitted by Administrations, either by letter to the C.C.I.R. or by submission at the IXth Plenary Assembly.

5.1 *Austria.*

With reference to the questions raised in the Report of Study Group XI (Moscow, 8 June 1958) concerning television standards for Bands IV and V, the Austrian Administration expresses the following opinion:

Considering

- (a) that, for reception in Bands IV and V, it is desirable to use the same system of apparatus as has been used so far for Bands I and III,
- (b) that, in future, colour television systems should be compatible with the monochrome systems now in operation,
- (c) that a widening of the band from 7 to 8 Mc/s would facilitate adjacent channel rejection,
- (d) that Austria is operating a television system in Bands I and III in accordance with the C.C.I.R. Recommendation, using 625 lines, a carrier spacing of 5.5 Mc/s and a channel width of 7 Mc/s;

the Austrian Administration has decided to accept for Bands IV and V a standard as indicated in (d) above, but with a channel separation of 8 Mc/s if this is generally adopted by European Administrations.

At the same time, the Austrian Administration expresses its desire for the introduction of uniform frequencies for the picture carriers and the colour sub-carriers in all European countries using 625 lines, which would facilitate the allocation of television frequencies in frontier areas and would make it possible to use offset carrier frequencies.

5.2 *Belgium.*

In order to reach a common standard for colour television in Bands IV and V, Belgium is ready to accept a standard of 625 lines with a channel spacing of 8 Mc/s and a spacing of 5.5 Mc/s between vision and sound carrier frequencies.

If, however, the adoption of a channel spacing of 8 Mc/s and a spacing of 6.5 Mc/s between vision and sound carrier frequencies is necessary in order to reach a common standard for colour television in Bands IV and V, Belgium would be prepared to come into line.

5.3 *Denmark.*

The television system at present in use in Denmark in Bands I and III has as its main parameters: 625-line definition, 7 Mc/s channel spacing and 5.5 Mc/s separation between vision and sound carriers. It would, therefore, be an advantage if a compatible colour television standard for Bands IV and V could have the same 5.5 Mc/s spacing between vision and sound carriers.

In view of the general desire to obtain a common television standard in Europe for Bands IV and V, the Danish Administration nevertheless is prepared to accept a spacing of 6.5 Mc/s between vision and sound carriers if the adoption of such a value could make a common standard possible.

In any case the Danish Administration is prepared to accept a channel spacing of 8 Mc/s in order to facilitate frequency planning and reduce mutual interference.

Furthermore, the Danish Administration is prepared to accept a colour sub-carrier of approximately 4.43 Mc/s if such a value is generally agreed upon.

5.4 *Finland.*

In regard to the standards to be used for television in Bands IV and V in Europe, Finland is prepared to accept an 8 Mc/s channel with 6.5 Mc/s separation between vision and sound carrier frequencies in conformity with Sweden, Denmark and Norway.

5.5 *France.*

The present view is that France intends to broadcast in Bands IV and V:

- a second black and white programme in the near future,
- a third programme, in colour, in the more distant future.

Although the technical standards in accordance with which these programmes will be broadcast have not yet been the subject of an official decision, already the following trend may be noted:—

5.5.1 *Black-and-White Programme.*

In order to facilitate the adaptation of receivers already in use in Bands I and III, and to ensure the unity of the black-and-white network, the broadcasting of the second programme on the wideband 819-line system is envisaged.

5.5.2 *Colour programme.*

- In so far as the colour programme is concerned, France will be prepared to put into operation a 625-line system, if this definition is adopted by the other European countries.
- This plan is not to pre-judge in any way the choice of the system itself which, in the present state of the studies, France considers to be premature.
- France considers that the system finally chosen should have a spacing between sound and vision carriers of at least 6.5 Mc/s.
- France will accept a division of Bands IV and V into 8 Mc/s channels if such a division can be adopted by the majority of European countries. She reserves the right, however, to use this sub-division by grouping two adjacent 8 Mc/s channels into one 16 Mc/s channel which can carry two emissions of nominal bandwidth greater than 8 Mc/s but with partially overlapping spectra.

5.6 *Italy.*

The Italian Administration will, in the very near future, use Band IV for monochrome television. For these emissions and for colour television emissions that will take place in the future the Italian Administration will use the same 625-line system now used in Bands I and III, with a channel width of 7 Mc/s and a separation of 5.5 Mc/s between vision and sound carriers.

Nevertheless, the Italian Administration is prepared to accept a channel spacing of 8 Mc/s if this would facilitate the establishment of a frequency assignment plan.

5.7 *Japan.*

Japan is using the following standards for monochrome television in the VHF bands:

- Number of lines—525
- Channel bandwidth—6 Mc/s
- Channel spacing—6 Mc/s
- Separation of vision and sound carriers—4.5 Mc/s

Japan has not yet come to any decision regarding the use of Bands IV and V. Consideration is now being given to the standards to be adopted for monochrome and colour television in Bands IV and V, but Japan has not yet reached any conclusions.

5.8 *Norway.*

The views of Norway are in accordance with the statements made by the other Scandinavian countries.

5.9 *Netherlands.*

The Netherlands' Administration wishes to retain the existing 625-line monochrome television system in Bands I and III (Gerber standards) for operation in Bands IV and V. While maintaining the existing spacing of the vision and sound carriers, the Netherlands' Administration is never-

theless prepared to consider an 8 Mc/s channel spacing in Bands IV and V, if this would facilitate frequency planning and the achievement of a common standard in these bands.

With regard to colour system standards, it is fully appreciated that the use of a common colour sub-carrier would, to a great extent, aid frequency planning.

As a result of work and of tests on colour systems, carried out in the Netherlands by the industry, the Netherlands' Administration is in favour of considering the use of a common colour sub-carrier frequency of 4.43 Mc/s approximately.

Note. — It has to be understood that a colour standard has to be compatible with the monochrome standard and, therefore, the carrier separation between vision and sound must be 5.5 Mc/s.

5.10 *People's Republic of Poland.*

The Administration of the People's Republic of Poland is greatly interested in the possibility of extensive unification of television standards for Bands IV and V. This interests results from the specific geographical situation of Poland on the boundary of the two 625-line television standards at present in use: one utilising 7 Mc/s channel bandwidth and the other 8 Mc/s.

For this reason, the proposal to arrange Bands IV and V so that the vision carriers should be spaced by 8 Mc/s is—in the opinion of the Administration of the People's Republic of Poland—an advantageous compromise solution, facilitating television network planning, when it is not possible, as at present, to arrange for uniform 625-line television standards.

At the same time, the Polish Administration announces that the monochrome television system in Bands IV and V applied in Poland will be characterised by the following main parameters:

- 625-line definition
- 8 Mc/s channel bandwidth
- the vision carrier will be located 1.25 Mc/s above the lower edge of the channel and unmodulated sound carrier will be located 0.25 Mc/s under the upper channel edge. In this way, the carriers of the transmitters will be spaced 6.5 Mc/s apart.

The above parameters will agree with the I.B.T.O. standard now utilized for Bands I and III.

5.11 *Roumanian People's Republic.*

The Administration of the Roumanian People's Republic is greatly interested in the possibility of uniform standards for television in bands IV and V, since this will largely facilitate frequency planning and the international exchange of television programmes.

The Roumanian Administration announces that the monochrome television system that will be used in the Roumanian People's Republic in Bands IV and V will have the following characteristics:

- definition: 625 lines
- channel width: 8 Mc/s
- the vision carrier will be 1.25 Mc/s above the lower channel limit and the unmodulated sound carrier 0.25 Mc/s below the upper limit. Thus, the spacing between these two carriers will be 6.5 Mc/s.

The above values are in conformity with the I.B.T.O. standards now in use for Bands I and III.

5.12 *Federal German Republic.*

The Federal German Administration, the German broadcasting companies and industrial enterprises have given further study to the problem stated in Doc. XI/68 of Moscow, 1958, and reached the following conclusions:

Support is given to the procedure for achieving a common colour television standard and, first of all, those parameters should be agreed upon which have an important bearing on frequency planning in Bands IV and V.

The opinion of the Federal German Administration on the questions stated in the concluding part of Doc. XI/68 is as follows:

Definition Standards: It is intended in the Federal German Republic to retain the 625-line; 7 Mc/s standard in Bands IV and V.

Channel Bandwidth: The view already voiced at the Moscow interim meeting is upheld that, in the interest of a common European standard and with a view to facilitating frequency planning, the Federal German Administration is willing to adopt a channel spacing of 8 Mc/s in Bands IV and V.

Location of the vision and sound carrier within the channel: As has been pointed out under Definition Standards above and stated at the Interim Meeting in Moscow, the German Administration intends to retain in Bands IV and V the 7 Mc/s standard and consequently a spacing of 5.5 Mc/s between vision and sound carriers, since Band IV must partly be used to fill in the gaps left by the Band III service.

Colour Sub-Carrier: Though the colour television tests to date were mostly made with a colour carrier at about 4.2 Mc/s, the German Administration, having reconsidered this question, is prepared to adopt a colour carrier higher in frequency, about 4.43 Mc/s, if this would enable a common standard to be achieved.

5.13 *United Kingdom.*

Over the past several years, the United Kingdom has made comprehensive studies of television standards and of the propagation of television signals in Bands IV and V, and the data obtained has been presented to C.C.I.R. Study Group XI. Of particular interest are the results of recent Band V field trials on 405-line and 625-line standards in the London area using high-power transmissions on a frequency of about 650 Mc/s.

The United Kingdom is now concluding its studies on the question of the television standards to be used in Bands IV and V and, until this has been done, it is not possible to state what conclusions will be reached. It is possible, however, to state that the United Kingdom would, in the interests of frequency planning, adopt 8 Mc/s channel spacing for Bands IV and V if Europe generally adopted that spacing. Further, should the United Kingdom decide to adopt 625-line standards in Bands IV and V, a 6 Mc/s video bandwidth and a spacing of 6.5 Mc/s between vision and sound carriers would be used.

5.14 *Sweden.*

Taking into account the importance of a common monochrome standard in Bands IV and V for frequency planning in these bands and for the later introduction of a colour system compatible with the monochrome standard, Sweden fully agrees with the general views expressed in Doc. No. XI/68 of Moscow—1958, and submits the following conclusions:

5.14.1 *Monochrome television.*

— *Definition standards*: The 625-lines, 7 Mc/s channel width standard now used in Bands I and III should be retained also in Bands IV and V.

— *Channel spacing*: If the use of an 8 Mc/s spacing enables a common standard to be achieved in Europe, Sweden supports the use of such a channel spacing in Bands IV and V.

- *Location of vision and sound carriers within the channel:* The 5.5 Mc/s separation between vision and sound carriers used in Bands I and III should be retained also in Bands IV and V.

Sweden would be prepared to adopt the 625-line 8 Mc/s channel width standard with 6.5 Mc/s separation between vision and sound carriers, if this would enable a common standard to be achieved in Bands IV and V throughout Europe.

5.14.2 *Colour television.*

Sweden recommends the use of a colour sub-carrier on a frequency of 4.43 Mc/s, if 5.5 Mc/s separation between vision and sound carriers is adopted.

5.15 *Switzerland.*

The present point of view is given in the table in § 6. The figures shown would, however, be reconsidered in the light of a possible future common standard.

5.16 *Czechoslovakia.*

The Administration of Czechoslovakia is greatly interested in the possibility of extensive unification of television standards for Bands IV and V. This interest results from the specific geographical situation of Czechoslovakia on the boundary of the two 625-line television standards at present in use: one utilizing 7 Mc/s channel bandwidth and the other 8 Mc/s.

For this reason, the proposal to arrange Bands IV and V so that the vision carriers should be spaced by 8 Mc/s is—in the opinion of the Administration of Czechoslovakia—an advantageous compromise solution, facilitating television network planning, when it is not possible, as at present, to arrange for uniform 625-line television standards.

At the same time, the Czechoslovakian Administration announces that the monochrome television system in Bands IV and V applied in Czechoslovakia will be characterized by the following main parameters:

- 625-line definition
 - 8 Mc/s channel bandwidth
 - the vision carrier will be located 1.25 Mc/s above the lower edge of the channel and unmodulated sound carrier will be located 0.25 Mc/s under the upper channel edge.
- In this way, the carriers of the transmitters will be spaced 6.5 Mc/s apart.

The above parameters will agree with the I.B.T.O. standard now utilized for Bands I and III.

5.17 *U.S.S.R.*

The Administration of the U.S.S.R. is greatly interested in the possibility of extensive unification of television standards for Bands IV and V. For this reason, the proposal to arrange Bands IV and V so that the vision carriers should be spaced by 8 Mc/s is—in the opinion of the Administration of the U.S.S.R.—an advantageous compromise solution, facilitating television network planning, when it is not possible, as at present, to arrange for uniform 625-line television standards.

At the same time, the U.S.S.R. Administration announces that the monochrome television system in Bands IV and V applied in U.S.S.R. will be characterized by the following main parameters:

- 625-line definition
 - 8 Mc/s channel bandwidth
 - the vision carrier will be located 1.25 Mc/s above the lower edge of the channel and the unmodulated sound carrier will be located 0.25 Mc/s under the upper channel edge.
- In this way the carriers of the transmitters will be spaced 6.5 Mc/s apart.

The above parameters will agree with the I.B.T.O. standard now utilized for Bands I and III.

	Definition Standard		Channel Spacing (Mc/s)	Separation of vision and sound carriers (Mc/s)	Colour Sub-carrier (Mc/s)	Notes
	Lines	Channel bandwidth (Mc/s)				
Austria	625	7	8	5.5	4.43 *	
Belgium	625	7 or 8	8	5.5 or 6.5		
Denmark	625	7 or 8	8	5.5 or 6.5	4.43 *	
Finland	625	7 or 8	8	5.5 or 6.5	4.43 **	
France			8 (16)			France foresees the provision of 16 Mc/s channels in particular to allow for the emission of an 819-line black and white programme. If a 625-line system were adopted for the emission of a colour programme the French Administration contemplates the use of 6.5 Mc/s separation between vision and sound carriers.
Italy	625	7	8	5.5		
Norway	625	7 or 8	8	5.5 or 6.5	4.43 **	
Netherlands	625	7	8	5.5	4.43	
Poland	625	8	8	6.5	4.43 *	
Federal German Republic	625	7	8	5.5	4.43	
United Kingdom			8			If the U.K. decides to adopt 625-line standards in Bands IV and V, an 8 Mc/s channel with a 6.5 Mc/s separation of vision and sound carriers would be used.
Sweden	625	7 or 8	8	5.5 or 6.5	4.43 **	
Switzerland	625	7	8	5.5	4.43	
Czechoslovakia	625	8	8	6.5	4.43 *	On account of the difficulties that may arise from the differences between the 8 Mc/s channel (with 6.5 Mc/s spacing of vision and sound carrier frequencies), used in Czechoslovakia in accordance with the I.B.T.O. standards, and the 8 Mc/s channel (with 5.5 Mc/s spacing between vision and sound carrier frequencies) proposed by certain countries adjoining Czechoslovakia, measures to reduce to a minimum the mutual interference between the two systems of channelling are under study.
U.S.S.R.	625	8	8	6.5	4.43 *	

* Probable value assuming a common standard for colour television is adopted in Europe.

** If 5.5 Mc/s separation of vision and sound carriers is adopted.

In the U.S.S.R. at present, colour television tests are still in hand, but the final choice of a colour sub-carrier frequency is likely to be 4.43 Mc/s if all other European countries agree on a common standard for colour television with this sub-carrier frequency.

6. Summary of Statements submitted by Administrations.

The following table gives a brief summary of the views put forward by the Administrations named in the preceding paragraph, proposing or considering the use of 625-line standards in Bands IV and V.

7. Conclusions.

Most European Administrations have reported on the question of the television standards they propose to adopt in Bands IV and V. Some Administrations have indicated that they have not yet reached a final decision on this question, while others have stated that their decision would be dependent on the achievement of a common standard in Europe. Nevertheless, it would appear that considerable progress has been made towards the realization of a common channel spacing of 8 Mc/s in Europe in Bands IV and V, and some progress towards the adoption of a common definition standard of 625-lines using either a 7 Mc/s channel bandwidth with 5.5 Mc/s separation between vision and sound carriers or an 8 Mc/s channel bandwidth with 6.5 Mc/s separation.* Many Administrations have indicated that they would be prepared to adopt a colour sub-carrier of the order of 4.43 Mc/s for a 625-line colour television system.

It is very desirable that those Administrations which have not submitted reports to the C.C.I.R. as requested in § 4 above, should do so as soon as possible, and in any case, should reach firm conclusions as to the standards they would propose to adopt for monochrome television and, if possible, colour television in Bands IV and V, well in advance of the next European VHF/UHF Broadcasting Conference which is likely to take place in the early autumn of 1960. Such a Conference might well be preceded by an interim meeting of Study Group XI. In that case, reports should be made in good time for this meeting in order that every effort could be made to achieve a common European standard.

REPORT No. 124 **

CHARACTERISTICS OF MONOCHROME TELEVISION SYSTEMS

(Study Group No. XI)

(Geneva, 1951 — London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

The following tables given for information contain details of a number of different monochrome television systems in use at the time of the C.C.I.R. Plenary Assembly, Los Angeles, 1959.

* The possibility of using fully an 8 Mc/s channel bandwidth but retaining 5.5 Mc/s separation of vision and sound carriers was also discussed.

** This report which replaces Report No. 83, was adopted by correspondence without reservation (see page 9).



TABLE I
CHARACTERISTICS OF MONOCHROME TELEVISION SYSTEMS

Item	Description of Item	System						
		405	525 (2)	625 (3)	Belgian 625	I.B.T.O. 625	819	Belgian 819
Video characteristics (See also Tables II and III for details of line and field synchronizing signals respectively)								
1	Number of lines per picture (frame) . . .	405	525	625	625	625	819	819
2	Field frequency (fields/second)	50	60	50	50	50	50	50
3	Interlace	2:1 *	2:1 *	2:1 *	2:1 *	2:1 *	2:1 *	2:1 *
4	Picture (frame) frequency (pictures/second) .	25	30	25	25	25	25	25
5	Line frequency and tolerance when operated non-synchronously (lines/second)	10,125	15,750	15,625 ± 0.1 %	15,625 ± 0.1 %	15,625 ± 0.05 %	20,475	20,475 ± 0.1 %
6	Aspect ratio (width: height)	4:3 *	4:3 *	4:3 *	4:3 *	4:3 *	4:3 *	4:3 *
7	Scanning sequence (lines) (fields)	Left to right * Top to bottom *	Left to right * Top to bottom *	Left to right * Top to bottom *	Left to right * Top to bottom *	Left to right * Top to bottom *	Left to right * Top to bottom *	Left to right * Top to bottom *
8	System capable of operating independently of power supply frequency	Yes *	Yes *	Yes *	Yes *	Yes *	Yes *	Yes *
9	Approximate gamma of picture signal . . .	0.4-0.5	0.45	0.5	0.5	0.5	0.6	0.5
10	Nominal video bandwidth (Mc/s)	3	4.2 (4.0)	5	5	6	10	5
Radio frequency characteristics (See also Table IV for ideal sideband characteristics of vision transmitters)								
a	Nominal radio-frequency bandwidth (Mc/s)	5	6	7	7	8	14	7
b	Sound carrier relative to vision carrier (Mc/s)	-3.5 *	+4.5 *	+5.5 *	+5.5 *	+6.5 *	11.15	+5.5 *
c	Sound carrier relative to nearest edge of channel (Mc/s)	+0.25 *	-0.25 *	-0.25 *	-0.25 *	-0.25 *	0.02	-0.25 *
d	Nominal width of main sideband (Mc/s)	3	4.2 (4)	5	5	6	10	5
e	Nominal width of vestigial sideband (Mc/s)	0.75	0.75	0.75	0.75	0.75	2	0.75
f	Type of polarity of vision modulation . .	A5 * positive Asymmetric sideband *	A5 * negative Asymmetric sideband *	A5 * negative Asymmetric sideband *	A5 * positive Asymmetric sideband *	A5 * negative Asymmetric sideband *	A5 * positive Asymmetric sideband *	A5 * positive Asymmetric sideband *
g	Synchronizing level as percentage peak carrier	< 3	100	100	< 3	100	< 3	< 3
h	Blanking level as percentage peak carrier . .	30	75	72.5-77.5 (75)	22.5-27.5	75	30	22.5-27.5
i	Difference between black level and blanking level as percentage peak carrier	5	2.875-6.75 (0)	3-6.5	3-6 (4)	3-5	5	3-6 (4)
j	Peak white level as percentage peak carrier .	100	≤ 15	10-12.5 (10-15)	100	10	100	100
k	Type of sound modulation	A3	F3 ± 25 kc/s 75 μs pre-emphasis 2: 1-1.43: 1 (20: 3-20: 7)	F3 ± 50 kc/s 50 μs pre-emphasis	A3 50 μs pre-emphasis	F3 ± 50 kc/s 50 μs pre-emphasis	A3 No pre-emphasis	A3 50 μs pre-emphasis
l	Ratio vision to sound effective radiated powers (1)	4: 1		5: 1	4: 1 (4)	2: 1-5: 1	4: 1	4: 1 (4)

* These characteristics are in accordance with Recommendation No. 212.

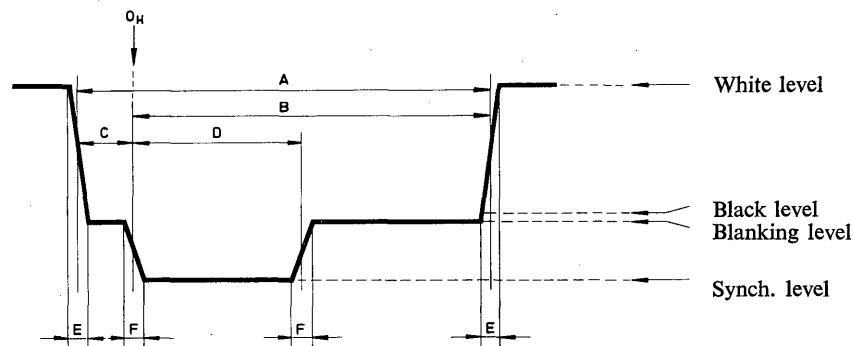
(1) The value to be considered are respectively the r.m.s. value of the carrier at the peak of the modulation envelope for the vision signal and the r.m.s. value of the unmodulated carrier for amplitude-modulated and frequency-modulated sound transmissions.

(2) Figures in brackets refer to Japanese 525-line system.

(3) Figures in brackets refer to Australian 625-line system.

(4) Tentative data.

TABLE II
Details of line synchronizing signals



Item	Description of Item	Durations for system: (Measured between half-amplitude points on the appropriate edges)													
		405		525		625 (1)		Belgian 625		I.B.T.O. 625		819		Belgian 819	
		%H	μ s	% H	μ s	% H	μ s	% H	μ s	% H (4)	μ s	% H	μ s	% H	μ s
H	Line period	100	98.8	100	63.5	100	64	100	64	100	64	100	48.84	100	48.84
A	Line blanking interval	17.7-19.2	17.5-19	16-18	10.2-11.4	18.5-19.2	11.8-12.3	18.7	11.8-12.2 (2)	18.4-19.5	11.8-12.5	19	9.2-9.8	18.4	9.9-4.2 (2)
B	Interval between time datum (O_H) and back edge of line blanking	16.2-17.2	16.0-17.0	14.3	> 9.1		(10-11)	16.5	10.2-11 (2)	16.1-17.3 (3)	10.3-11.3 (3)	17.8	8.9	16.4	7.8-8.6 (2)
C	Front porch	1.52-1.95	1.5-2.0	> 2.7	> 1.71	2.2-8	1.3-1.8	2.2	1.2-1.6 (2)	1.9-2.35	1.2-1.5	1.2	0.5-0.7	2	0.8-1.2 (2)
D	Synchronizing pulse	8.1-10.1	8-10	6.6-8.6	4.19-5.46	7.7-7	4.5-4.9	7.8	4.8-5.2 (2)	7.8-3	4.5-5.3	5.2	2.4-2.6	7.2	3.4-3.8 (2)
E	Build-up time (10-90%) line blanking edges	0.26-0.51	0.25-0.5	1	0.64	0.31-0.62	0.2-0.4	0.5	0.2-0.4 (2)	0.3-0.7	0.2-0.45	0.4	0.17-0.23	0.4	0.1-0.3 (2)
F	Build-up time (10-90%) line synchronizing pulses	$\leq$ 0.26	$\leq$ 0.25	0.4	0.25	0.31-0.62	0.2-0.4	0.5	0.2-0.4 (2)	0.2-0.4	0.13-0.23	0.25	0.10-0.14	0.4	0.1-0.3 (2)

1) Values in μ s are the primary ones. Figures in brackets refer to Australian 625-line system.

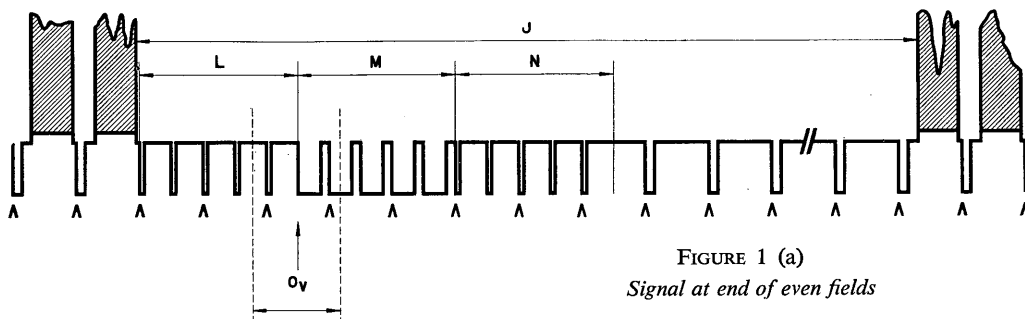
2) Tentative data.

3) Calculated values.

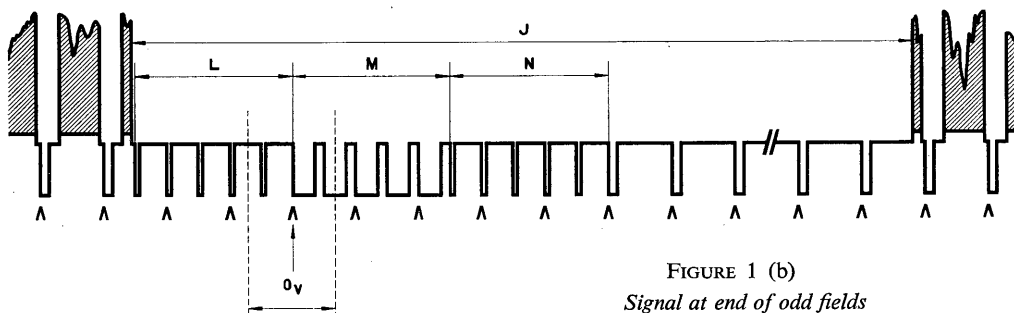
4) % H values are given in rounded-off figures.

TABLE III
Details of field synchronizing waveforms

1. Diagrams applicable to all systems except standard 819-line system



See Fig. 1 (c)

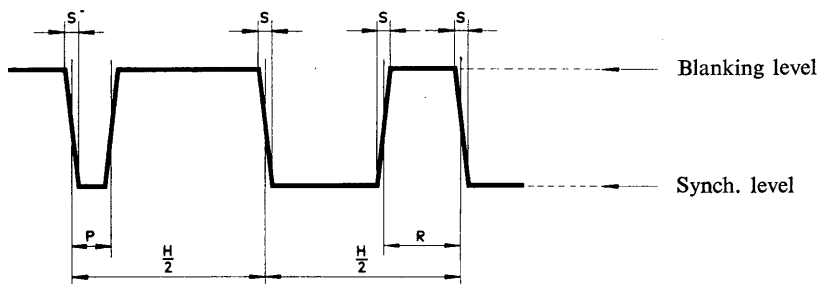


See Fig. 1 (c)

Note 1: $\wedge \wedge \wedge$ indicates unbroken sequence of line synchronizing edges through field blanking period.

Note 2: At end of *even* fields, field synchronizing edge (O_v) falls midway between two line synchronizing edges if L is an *odd* number of half-line periods as shown.

Note 3: At end of *odd* fields, field synchronizing edge (O_v) coincides with a line synchronizing edge if L is an *odd* number of half-line periods as shown.



Note: Durations measured to half-amplitude points on appropriate edges

FIGURE 1 (c)

Details of equalizing and synchronizing pulses

TABLE III (continued)

Details of field synchronizing waveforms

2 Diagrams applicable to the standard 810-line system

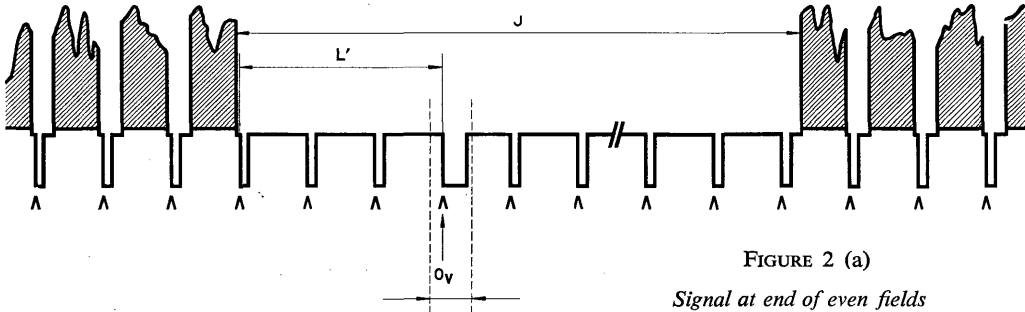


FIGURE 2 (a)

Signal at end of even fields

See Fig. 2 (c)

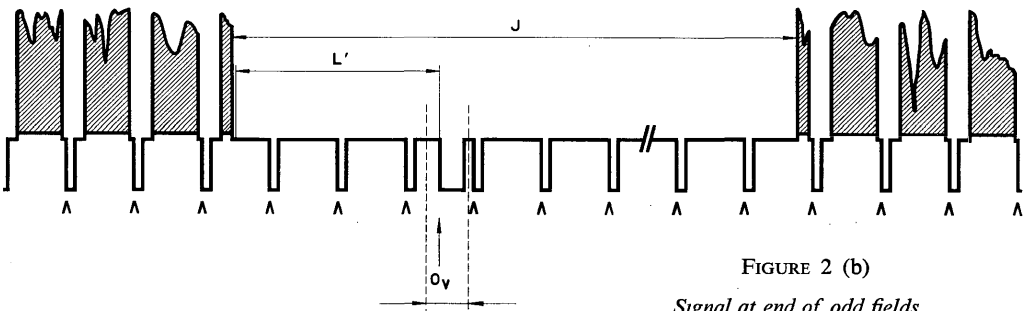


FIGURE 2 (b)

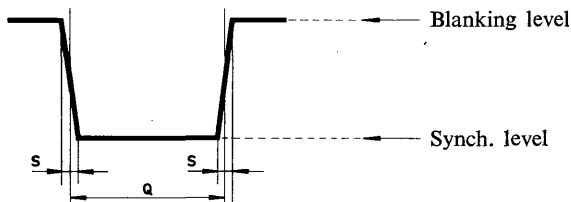
Signal at end of odd fields

See Fig. 2 (c)

Note 1 : $\wedge \wedge \wedge$ indicates unbroken sequence of line synchronizing edges through field blanking period.

Note 2 : At end of *even* fields the field synchronizing edge (O_v) coincides with a line synchronizing edge.

Note 3 : At end of *odd* fields the field synchronizing edge (O_v) falls midway between two line synchronizing edges.



Note : Durations measured to half-amplitude points on appropriate edges

FIGURE 2 (c)

Details of equalizing and synchronizing pulses

TABLE III (continued)

Item	Description of Item	System													
		405		525 ⁽⁵⁾		625 ⁽⁶⁾		Belgian 625		I.B.T.O. 625		819		Belgian 819	
<i>V</i>	Field period (ms)	20		16·667		20		20		20		20		20	
<i>H</i>	Line period (μs)	98·8		63·5		64		64		64		48·84		48·84	
<i>J</i>	Field-blanking period	(13·15·5) <i>H</i> ⁽²⁾ + 18·25 ⁽³⁾ μs		(13·21) <i>H</i> + 10·7 μs		(18·22) <i>H</i> + 12 μs ((18·22) <i>H</i> + 11·7 μs)		(20·21) <i>H</i> + 12 μs		(23·27) <i>H</i>		41 <i>H</i>		(29·30) <i>H</i> + 9 μs	
<i>K</i> (1)	Build-up times (10·90%) of field-blanking edges (μs)	0·25-0·5		6·35		≤ 6 (·4)		≤ 6·4		0·2-6·4		< 0·2		< 4·9	
<i>L</i>	Duration of first equalizing pulse sequence . .	(4)		3 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i> or 3 <i>H</i>				3·5 <i>H</i>	
<i>L'</i>	Nominal interval between beginning of field blanking and leading edge of field synchro- nizing pulse — <i>Ov</i>											3 <i>H</i>			
<i>M</i>	Duration of synchronizing pulse sequence . .	4 <i>H</i>		3 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i> or 3 <i>H</i>				3·5 <i>H</i>	
<i>N</i>	Duration of second equalizing pulse sequence .			3 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i>		2·5 <i>H</i> or 3 <i>H</i>				3·5 <i>H</i>	
		% <i>H</i>	μs	% <i>H</i>	μs	% <i>H</i>	μs	% <i>H</i>	μs	% <i>H</i> ⁽⁸⁾	μs	% <i>H</i>	μs	% <i>H</i>	μs
<i>P</i>	Duration of equalizing pulse			3·6	2·54	3·4-3·75	2·2-2·4 (2·2-3)	3·7	2·3-2·5 (7)	3·5-4·15	2·25-2·65			3·5	1·6-1·8 (7)
<i>Q</i>	Duration of field synchronizing pulse	38·5-42·5	38-42	42·6	27·1		(26·5-26·9)	42	26·8-27·2 (7)			41	19-21	43	20·6-21 (7)
<i>R</i>	Interval between field synchronizing pulses .	11·5-7·5	11·4-7·4	7·4 (6-8)	4·7 (3·84-5·04)	7·7-7	4·5-4·9 (5·1-5·5)	7·8	4·8-5·2 (7)	7·8-3	4·5-5·3			7·2	3·4-3·8 (7)
<i>S</i>	Build-up times (10·90%) of synchronizing signal edges	≤ 0·26	≤ 0·25	0·4	0·25	0·31-0·62	0·2-0·4	0·5	0·2-0·4 (7)	0·2-0·4	0·13-0·26	< 0·4	< 0·2	0·4	0·1-0·3 (7)

Notes concerning table III.

(1) Not indicated on diagram.

(2) The coefficient of *H* is an integral multiple of 0·5.(3) Actually the value of *A* given in Table II.(4) In the 405-line system are no equalizing pulses; the field-blanking period *J* commences in advance of the field-synchronizing pulse sequence by an interval of from 0·15 *H* to 0·51 *H*.

(5) Figures in brackets refer to Japanese 525-line system.

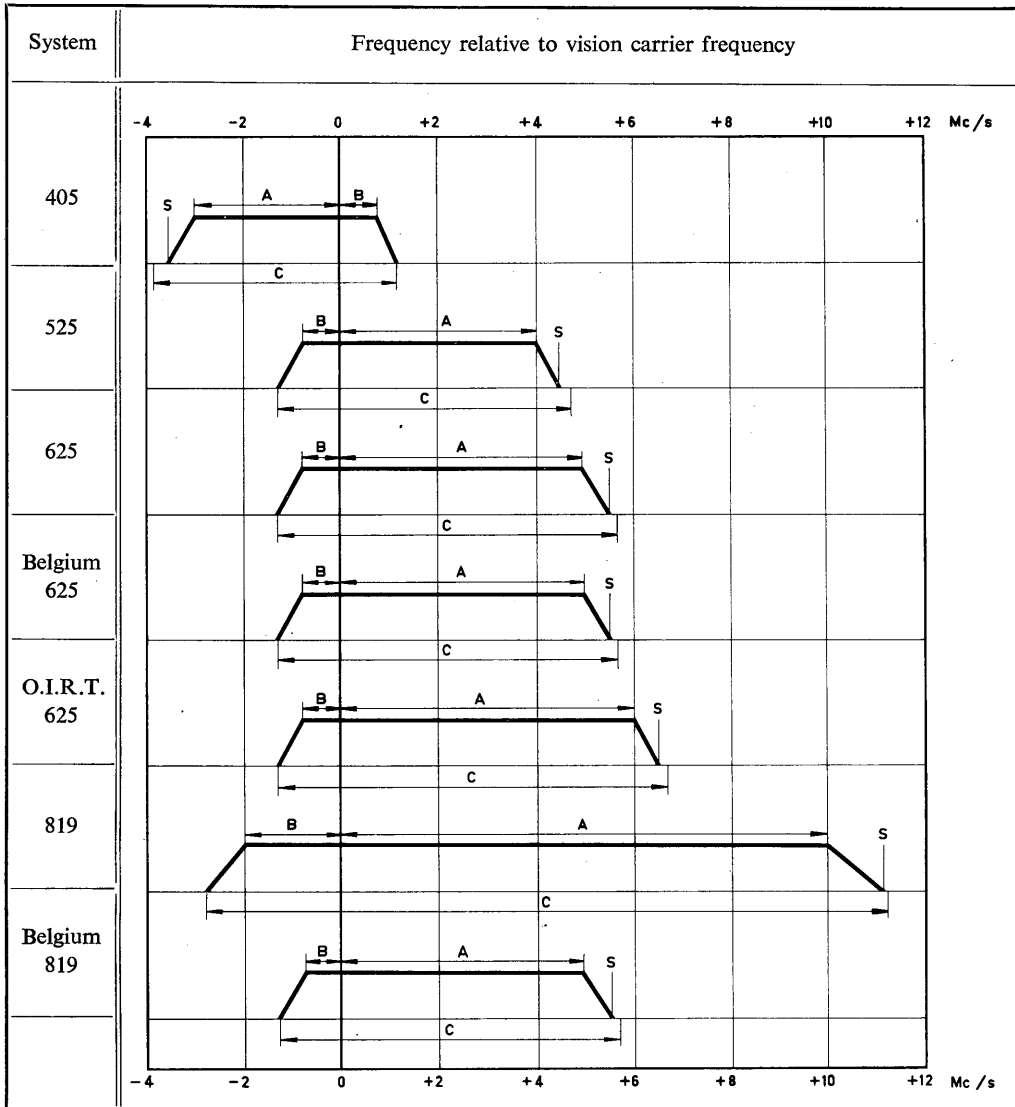
(6) Values in μs are the primary ones. Values in brackets refer to Australian 625-line system.

(7) Tentative data.

(8) % *H* values are given in rounded-off figures.

TABLE IV

Ideal frequency-characteristics for vision transmitters
(See Table I for precise frequency spacings)



Notes: (1) *S* indicates position of sound carrier. (2) *C* indicates limits of radio frequency channel. (3) *A* = nominal width of main sideband. (4) *B* = nominal width of vestigial sideband.

REPORT No. 125 *

**RATIO OF THE WANTED TO THE UNWANTED SIGNAL
IN MONOCHROME TELEVISION**

(Question No. 119 (XI))

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

This report has been prepared using the available results of subjective tests on the tolerable ratios "wanted signal/unwanted signal" in monochrome television.

The protection ratios given in this report are considered acceptable for a short percentage of the time, not precisely defined, but assumed to be between 1% and 10%.

The protection ratios refer to a viewing distance of four times the picture height.

The protection ratios refer to the limit of just tolerable interference: protection ratios for just perceptible interference would be 6 to 10 db higher.

When utilizing the protection ratios, suitable allowance will have to be made for fading by adding to these ratios the root-sum-square of the fading of the wanted and unwanted signals. Alternatively, the allowance for fading can be determined using the curves of field strengths exceeded for 1% or 10% of the time when the fading of the wanted signal is small compared with the fading of the unwanted signal.

No account has been taken of the possible effect of using directional receiving antennae or of the advantage which might be gained by using different polarizations for transmission of the wanted and unwanted signals. The protection ratios quoted refer in all cases to the signals at the input of the receiver.

The values to be considered are respectively the r.m.s. value of the carrier at the peak of the modulation envelope for the television signal and the r.m.s. values of the unmodulated carrier for amplitude-modulated and frequency-modulated sound transmissions.

1. Interference within the same channel — Protection ratio for the picture signal when the wanted and unwanted signals have the same line frequency.

1.1 *Carriers separated less than 1000 c/s but not synchronized*: just tolerable interference: 45 db.

1.2 *Carriers separated by 2/3 of the line frequency*: just tolerable interference: 30 db.

This figure may be reduced to 20 db, if a carrier separation equal to a multiple of the field frequency can be maintained with a total deviation less than 5 c/s; the line frequency should be kept constant to within 5×10^{-6} and each transmitter should have a frequency tolerance of not more than ± 2.5 c/s. The 20 db figure is at present valid for 525- and 625- line systems when there is one unwanted transmitter. More tests are needed before this figure can be applied to other television systems or to the case of more than one unwanted transmitter.

1.3 *Carriers separated by 1/2 of the line frequency*: just tolerable interference: 27 db.

* This Report which replaces Report No. 82, was adopted by correspondence without reservation (see page 9).

2. Interference within the same channel — Protection ratio for the picture signal when the wanted and unwanted signals have different line frequencies.

2.1 *Carriers separated less than 1000 c/s but not synchronized*: just tolerable interference: 45 db.

2.2 *Carriers separated by 1/2 or 2/3 or the line frequency of the wanted signal*: As in § 1.2 and 1.3 the offset brings an improvement in the protection of the picture signal. This improvement, however, is reduced, since the line frequency of the unwanted signal is different from the line frequency of the wanted signal; the amount of the reduction depends on the relation between the line frequencies. More tests are needed before figures can be given for the protection ratios in this case.

3. Adjacent-channel interference.

The worst interference on the picture signal results from the sound transmission in the adjacent channels. The figures given below relate to the case when the separation between the vision carrier and the adjacent channel sound carrier is 1.5 Mc/s.

3.1 *Frequency-modulated sound carrier*: just tolerable interference: — 6 db.

3.2 *Amplitude-modulated sound carrier*: just tolerable interference: 0 db.

Fairly conservative values have been chosen to take account of the divergence in performance between different types of television receivers. However, future developments in receiver design will probably enable somewhat higher interfering signals to be tolerated in all cases.

4. Overlapping-channel interference.

In the attached figure, curves are given for the protection ratio required when a television signal, using 819, 625, 525 or 405 lines suffers interference from a vision signal of any of the systems or by a frequency-modulated sound signal. The curves cover the case when the carrier of the interfering signal lies within the vision channel of the wanted transmission.

If the interfering signal is an amplitude-modulated sound signal, 5 db should be added to the protection ratios shown by the curves. These curves are tentative and may require modification in the light of further experience.

It is theoretically possible to gain a further advantage by the use of offset methods using a frequency separation between the carriers equal to an odd multiple of half the line frequency. Further tests are needed before it can be said what precise advantage could be derived. Variation of line frequency would render difficult offsetting at high multiples of half the line frequency.

In the particular case of overlapping sidebands known as the “tête-bêche” arrangement, the protection ratio can be estimated roughly from the curves in the attached figure and from the rejection afforded to the unwanted carrier. More tests are needed before further guidance can be given for the protection ratios required for specific cases.

5. Protection ratio for the sound signal (for just tolerable interference).

5.1 *Wanted und unwanted signals frequency-modulated*: 20 db.

5.2 *Wanted and unwanted signals amplitude-modulated*:

for a frequency difference below the audio-frequency range: 30 db,

for a frequency difference within the audio-frequency range: 40 db,

for a frequency difference above the audio-frequency range: 15 db.

5.3 *Wanted signal amplitude-modulated, unwanted signal frequency-modulated :*

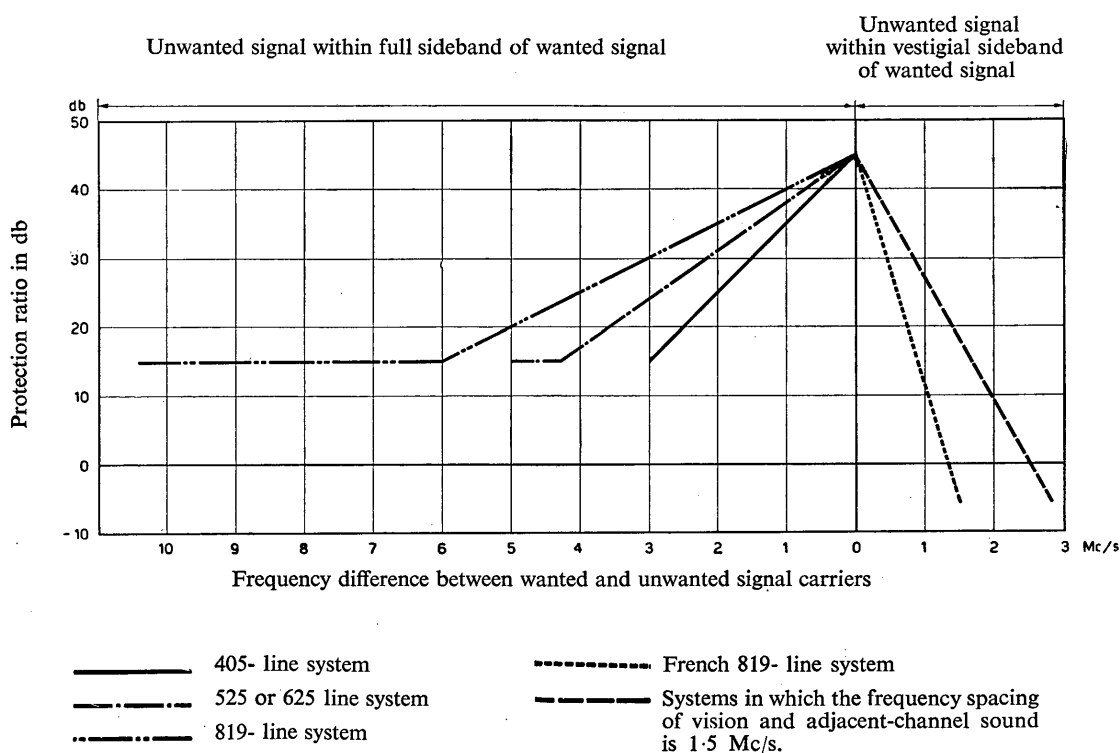
no frequency difference: 40 db,
 25 kc/s frequency difference: 30 db,
 50 kc/s frequency difference: 12 db.

5.4 *Wanted signal frequency-modulated, unwanted signal amplitude-modulated : 20 db.*

The above quoted figures, while giving the protection ratios required, will, in practice, be used to determine the frequency separation which may be needed between the sound carriers.

The C.C.I.R. is of the opinion that Question No. 119 (XI) should remain on the agenda and that further theoretical and experimental work should continue on this question.

PROTECTION RATIOS REQUIRED BY VISION SIGNAL AGAINST UNWANTED
 VISION OR FREQUENCY-MODULATED SOUND SIGNAL



Note 1 : For an amplitude-modulated sound signal the protection ratios required are about 5 db higher.

Note 2 : The above curves do not take into consideration the actual response of the receiver within the full sideband of the wanted signal; in this range the response is assumed to be 0 db with reference to the vision carrier. Any general departure from this should be noted in computing the effective protection ratio.

Note 3 : It follows, for receivers of the types used for the tests described in Documents 209 and 224 of Warsaw, 1956, that in the vestigial sideband, the line marked " French 819 line system " would be preferable to the actual dotted line for systems in which the frequency spacing of vision and adjacent-channel sound

carrier is 1.5 Mc/s. However, further experimental confirmation including other types of receiver is necessary before a change of the curve could be recommended.

Note 4: It should be noted that for interference within the same channel and with a considerable frequency difference, an advantage can be obtained from the use of carrier offset, as mentioned in Documents XI/5, XI/10 and XI/33 of Moscow, 1958. However, more thorough work will be required before specific figures can be given for the various television standards.

REPORT No. 126 *

ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES

(Question No. 152 (XI))

(Los Angeles, 1959)

It appears that during recent years extensive studies have been made in many laboratories on the assessment of the quality of television pictures and the respective methods of measurement, both for monochrome and colour television. Since it would appear that these studies cannot yet be considered to be concluded, it seems appropriate, with a view to facilitating future work, to give a list of documents and publications bearing on this question.

Such a list would serve, on the one hand, to avoid duplication of work, and on the other hand, to enable comparisons to be made with results already found elsewhere. It may be extended to include subsequent publications on this subject and would be a valuable aid, within the scope of Question No. 152 (XI), in arriving at suitable standard methods for measuring the various kinds of picture distortion in television.

List of documents concerning Question No. 152 (XI).

1. A simple test picture for the assessment of the quality of monochrome television pictures (Doc. No. XI/3 of Moscow, 1958).
2. An equipment for electro-optical measurements of television image quality (Doc. No. XI/11 of Moscow, 1958).
3. Method of measurement of interlacing quality on television receivers (Doc. No. XI/12 of Moscow, 1958).
4. Direct measurement of noise on the receiver screen (Doc. No. XI/24 of Moscow, 1958).
5. Apparatus for the measurement of signal-to-noise ratio in video signals (Doc. No. XI/25 of Moscow, 1958).
6. JESTY, L. C. Relation between Picture Size, Viewing Distance and Picture Quality. *Proc. I.E.E.* 105, B, (February 1958).
7. Measurement of random noise in television pictures (Doc. No. 39 of Los Angeles, 1959).
8. Method of measuring the numerical characteristics of gamma correctors (Doc. No. 124 of Los Angeles, 1959).
9. Influence of the colour parameters of the television receiver on the quality of colour reproduction (Doc. No. 125 of Los Angeles, 1959).
10. Effect of subcarrier frequency on luminance (Doc. No. 126 of Los Angeles, 1959).
11. Assessment of the luminance and chrominance of television pictures (Doc. No. 145 of Los Angeles, 1959).

* This Report was adopted unanimously.

REPORT No. 127 *

INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING

(Complement to Report No. 89)

(Question No. 102 (XII) and Study Programme No. 167 (XII))

(Los Angeles, 1959)

The information contained in the present report is supplementary to that of Report No. 89 and represents the results of the work carried out since the VIIIth Plenary Assembly of the C.C.I.R. Warsaw, 1956.

Document XII/1 (United Kingdom) of Los Angeles, 1959, summarizes the data presented at various times regarding the protection ratio of the wanted to unwanted signal that is required for just tolerable interference at various values of separation of carrier frequencies. The graphs of the document are given in Fig. 1. A summary of the conditions of the Post Office tests is also given in the document and is reproduced in § 3 of the Annex.

Doc. XII/6 (India) of Los Angeles, 1959, describes work carried out in connection with Question No. 102 (XII). Protection ratios required against A1 emissions both for speech and music programmes, A2 and A3 emissions for music programmes have been assessed. The results are given in § 4 of the Annex.

The Indian document takes into consideration the frequency tolerance standards laid down in the Atlantic City Radio Regulations. The summary is confined to two limiting cases, namely frequency separations of 0 and 5 kc/s respectively and indicates the protection figures required for various types of emission. The document also states that the results refer to steady state conditions and that an appropriate allowance should be made for fading.

An analysis of selectivity characteristics of receivers in use in India is also given in the document. Extensive tests were carried out to investigate from the point of view of listeners' satisfaction the effect of reducing the bandwidth of broadcast transmissions on overall quality.

The conclusion in the Indian document is that it is necessary to maintain the normal bandwidth of modulating frequencies to well beyond 5 kc/s. Any modifications to the design of broadcast receivers tending to attenuate frequencies at 5 kc/s and lower will, therefore, result in serious deterioration in the quality of reception.

* This Report was adopted by correspondence without reservation (see page 9).

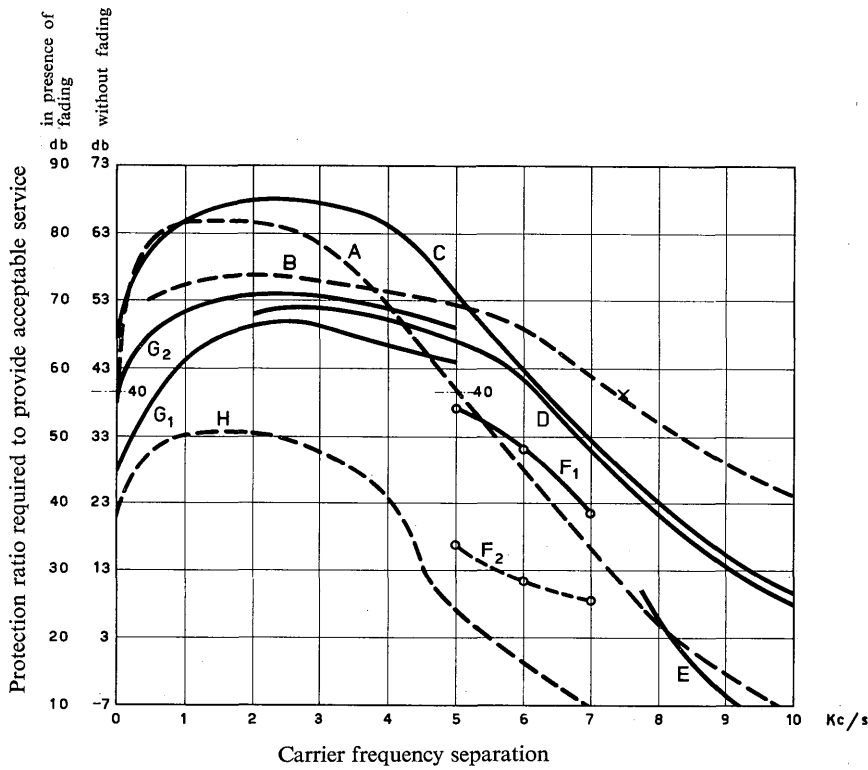


FIGURE 1

Protection ratios required to provide acceptable service

DESIGNATION OF CURVES

A*	Van der Pol (1933).	F ₂ **	B.P.O. tests, 1956 (whistle filter).
B*	Braillard (C.C.I.R., Bucharest, 1937).	G ₁ **	Indian tests (50 % satisfaction).
C*	B.P.O. tests, 1948.	G ₂ **	Indian tests (90 % satisfaction).
D**	B.P.O. tests, 1950.	H**	Curve used by the I.F.R.B., 1956 for HF broadcast plans.
E**	B.P.O. tests, 1951.		
F ₁ **	B.P.O. tests, 1956 (no filter).		

* Criterion of test — *Just perceptible interference.*

** Criterion of test — *Just tolerable interference.*

ANNEX

1. Conditions of test for Curve A.

The tolerable signal-to-interference ratio (with the receiver tuned to the wanted signal) was chosen as the criterion of receiver sensitivity.

The receiver sensitivity was adjusted to apply 150 mW low frequency power to the loudspeaker, the wanted signal being modulated by a 400 c/s tone to a depth of 30%. The quasi-maximum of the modulation of the interfering signal corresponded to a modulation index of 90%.

The amplitude of the interfering signal was then increased up to the point when its interfering effect on an unmodulated wanted signal was *just perceptible* to the ear at a distance of about 50 cm from the loudspeaker.

Further, if the wanted signal was also modulated, the above ratio may be multiplied by a factor between 3 and 5.* (Documents of the European Radiocommunication Conference, Lucerne, 1933, pp. 280-282 and Documents of the Fourth Reunion of the C.C.I.R., Bucharest, 1937, Vol. I, 109-112).

2. Conditions of test for Curve B.

Similar conditions to those of Curve A, but relating to very high quality reception. (Documents of the C.C.I.R., Bucharest, 1937, Vol. 1, 241.)

3. Conditions of tests for Curves C, D, E and F (British Post Office tests).

TABLE I

Test	Date of test	Wanted Signal		Unwanted Signal	
		Type	Modulation Index	Type	Modulation Index
C	1948	Music (0.8 kc/s)	30% average, peaking to 100% occasionally	Speech (0.8 kc/s)	30% average, peaking to 100% occasionally
D	1950	Broadcast speech		Telephony (0.3 kc/s)	70%
E	1951			Speech (0.6 kc/s)	30% average, peaking to 100% occasionally
F	1956			Music (6 db down at 4.6 kc/s)	30% average, peaking to 100% occasionally

The conditions under which test F were conducted require some detailed comment.

A "standard" condition of co-channel interference was set up, this in the first place providing an interfering broadcast signal 23 db below the wanted carrier level. As finally set up, however, short-term Rayleigh-type fading was introduced and, on the basis of some practical evidence, this was taken to require the co-channel protection ratio to be increased to 33 db. An allowance of

* Note by the Director of the C.C.I.R. The original van der Pol curve was plotted as the ratio of the "tolerable interfering signal to the wanted signal". Accordingly, with the curve A of Fig. 1, which is plotted as the ratio of the wanted signal to the interfering signal this factor should be 1/3 to 1/5 (— 9.5 to — 14 db).

7 db for long-term fading would thus give the figure of 40 db for planning purposes as used at the Mexico City Broadcasting Conference, 1948. The tests F, however, were carried out with artificially produced short-term fading only and all adjacent channel figures therefore relate to a co-channel protection ratio of 33 db. In the final presentation, these figures have therefore been reduced by 10 db to equate the results to the non-fading conditions used for all other tests. The ordinate has been so labelled that protection ratios can be read off either for non-fading conditions, or for full fading conditions incorporating a total allowance of $10 + 7 = 17$ db for short-term and long-term fading. For some of these measurements under test F a simple whistle filter was placed in the loudspeaker input leads so that the improvement in protection ratio that might readily be gained by reducing the audible heterodyne whistle at 5, 6 and 7 kc/s could be assessed.

4. Conditions of test for Curve G₂ (Indian tests with 90% listener satisfaction).

See Table II.

TABLE II

Wanted signal	Interfering emission	Frequency separation (kc/s)	Protection ignoring frequency tolerance (db)	Maximum frequency tolerance in the shared bands (Atlantic City) (c/s)	Protection taking into account the tolerance in Col. 5 (db)
Speech	A1-fixed (40 w.p.m.)	0	26.5	150	33.5
	A1-mobile (40 w.p.m.)	0	26.5	1000	44.5
	A2-fixed (mod. at 525 c/s)	0	35	150	42
	A2-mobile (mod. at 525 c/s)	0	35	1000	49
	A3-fixed (mod. at 3 kc/s max.)	0	33	150	40
	A3-mobile (mod. at 3 kc/s max.)	0	33	1000	50
	A3-Broadcasting	0	33	150	44
	A1-fixed (40 w.p.m.)	5	41.5	150	43
	A1-mobile (40 w.p.m.)	5	41.5	1000	47
	A2-fixed (mod. at 525 c/s)	5	39	150	43
	A2-mobile (mod. at 525 c/s)	5	39	1000	49
	A3-fixed (mod. at 3 kc/s max.)	5	48	150	50
	A3-mobile (mod. at 3 kc/s max.)	5	48	1000	52
	A3-Broadcasting	5	48	150	49
	A3-Broadcasting	0	33	645	51.5
	A3-Broadcasting	5	48	645	50.5
Music (Vocal)	A1-fixed (40 w.p.m.)	0	27.5	150	36
	A1-mobile (40 w.p.m.)	0	27.5	1000	42.5
Music (Instrumental)	A2-fixed (mod. at 525 c/s)	0	24	150	28.5
	A2-mobile (mod. at 525 c/s)	0	24	1000	36
Music (Vocal)	A3-fixed (mod. at 3 kc/s max.)	0	26	150	34
	A3-mobile (mod. at 3 kc/s max.)	0	26	1000	41.5
	A1-fixed (40 w.p.m.)	5	37	150	39
	A1-mobile (40 w.p.m.)	5	37	1000	43
Music (Instrumental)	A2-fixed (mod. at 525 c/s)	5	39	150	40
	A2-mobile (mod. at 525 c/s)	5	39	1000	43
Music (Vocal)	A3-fixed (mod. at 3 kc/s max.)	5	42.5	150	44
	A3-mobile (mod. at 3 kc/s max.)	5	42.5	1000	46.5

5. Conditions of test for Curve H.

Curve of the minimum protection ratio used by the I.F.R.B. for high-frequency broadcasting planning, which is, for stable transmitters (± 20 c/s). Any 5 kc/s whistle effects are ignored and the tests relate to operational conditions where the wanted field strength is considerably stronger (by at least 20 db) than the unwanted field strength. (Information furnished by the I.F.R.B.)

6. Comments on results.

With such a variety of test arrangements and particularly of types of receiver employed, it cannot be expected that close uniformity of results would be obtained; this is confirmed in Fig. 1. The rather less stringent protection resulting from test F, may imply that the 10 db factor allowed for short term fading is unnecessarily high. It may also, in part, be a consequence of the reduced bandwidth of the interfering signal as compared with that used for some of the earlier tests.

It will be noted that the I.F.R.B. curve H gives protection ratios substantially lower than any of the measured data. A further point of considerable interest is that the introduction of simple whistle filters appears to reduce the required protection ratio at frequency spacings of the order of 5 to 7 kc/s by as much as 12 to 20 db.

REPORT No. 128 *

BEST METHOD FOR CALCULATING THE FIELD STRENGTH PRODUCED BY A TROPICAL BROADCASTING TRANSMITTER

(Question No. 154 (XII))

(Warsaw, 1956 — Los Angeles, 1959)

Docs. Nos. 229 and 357 of Warsaw considered the currently used C.R.P.L. and S.P.I.M. methods of calculating the sky-wave field strength from a broadcast transmitter in the tropical zone. At the VIIIth Plenary Assembly, the Study Group came to the conclusion that the methods were inadequate and that further studies were required to derive a satisfactory method.

The following contributions to Question No. 154 (XII) were submitted to the IXth Plenary Assembly: Docs. XII/2 (United Kingdom), XIII/3 (French Overseas Territories) and XIII/7 (India) of Los Angeles, 1959 and they are summarized in this Report.

1. Doc. XII/2 (United Kingdom).

Question No. 154 (XII) asks what is the best method for calculating the field strength produced at the earth's surface by the indirect ray by a transmitter situated in the "tropical zone" (as defined in Appendix No. 16 of the Radio Regulations, 1947) under various conditions and in particular at distances up to 800 km and from 900 to 4000 km from the transmitter.

* This Report which replaces Report No. 88, was adopted by correspondence without reservation (see page 9).

In recent years work has, been carried out in the United Kingdom by the Department of Scientific and Industrial Research covering this particular problem and the results have been described in a paper by W. R. Piggott **. In this paper the author refers to the new data now available for amendment of the basic factors used in earlier standard methods of field strength calculation. With this new data and a fresh approach to the derivation of the various possible propagation modes, a method of calculation is described which covers the problem set by Question No. 154 (XII).

In effect the method proposed is comparable with that given in Circular No. 462 of the National Bureau of Standards in the U.S.A. The original curves of absorption index K are, however, replaced by new curves which take into account more recent measurements of absorption in tropical latitudes including those at Singapore (Malaya) and Ibadan (Nigeria) and also allow for the finite recombination time of the absorbing layers. It is interesting to note that the new K -curves make allowance for greater absorption after sunset than had been allowed in the Circular No. 462 data.

The final results are given in terms of the median values of field strength set up by a 1 kW transmitter and will need to be weighted by allowances for fading of the signal. At present little is known about the characteristics of fading of HF signals reflected at steep angles of incidence from the ionosphere but it is hoped that studies being made in this and other countries of C.C.I.R. Question No. 154 (XII) will provide the necessary quantitative data.

Attenuation is drawn to the statement on page 6 of the paper by Piggott regarding the effect of scattering at low latitudes near the geomagnetic equator and further data on this aspect are required.

2. Doc. XII/3 (French Overseas Territories).

This document discusses the main characteristics of tropical broadcasting. The paper includes graphs indicating the influence of antenna gain, directivity, absorption, E and F layer reflections, etc., for ranges up to 4000 km.

The method of calculating the graphs as well as their interpretation are given and certain conclusions concerning the main requirements for a rational use of tropical broadcasting are drawn as follows:

- absorption: An attempt should be made to absorb as much as possible fields due to all reflections other than the first.
- antennae with adequate directivity should be used without creating undesirable concentration.
- concerning the working frequency, one alternative would be to choose a frequency of about two-thirds the average critical frequency for F layer operation both by day and night. This method would be economical in power but would have drawbacks arising from sporadic E layer reflections, interference, echoes, etc. Another method would be to choose a rather low frequency distinctly below the critical frequency of the E layer for daytime operation. At night the frequency would have to be increased to a limited extent for operation with the F layer. In this case antennae with adequate directivity and with facility for variation of the transmission angle would have to be used.

2.1 Method of calculation.

The field at the receiver is obtained by the quadratic summation of the different components due to each of the possible routes of the sky-wave, neglecting the ground wave whose range is very restricted. The antennae recommended radiate only a small part of their energy at horizontal incidence and, as they are horizontally polarized, the attenuation of the direct wave by ground effect is very rapid. We are limited in the present study to an examination of the effect of the first four routes simultaneously possible.

** W. R. PIGGOTT: The Calculation of the Median Sky Wave Field Strength in Tropical Regions. *D.S.I.R. Radio Research Special Report No. 27*, H.M. Stationery Office, London, 1958.

Each of the components is calculated, making allowance for:

- the attenuation of the field by propagation (distance attenuation),
- the antenna gain used, knowing that its total radiated power is 1 kW,
- the attenuation due to D layer absorption.

The graphs are valid in the particular azimuthal plane of the antenna, i.e. in the vertical plane perpendicular to the horizontal wires of the antenna and passing through its centre.

2.2 *Method of presenting the graphs.*

The graphs show the level of the field received as a function of the distance, for certain frequencies which would be transmitted from Dakar, at peak listening hours (0800, 1200 and 2000 hours LMT) at a certain time of year and at low, medium and high sunspot numbers, corresponding respectively to the Wolf numbers 10, 70 and 150.

The level is indicated in decibels as a ratio of the reference field of 300 $\mu\text{V/m}$, which is regarded as practicable for listeners with an ordinary six-transistor receiver and generally sufficient to procure a signal/noise protection ratio better than or equal to 40 decibels.* However, at periods of intense noise, it is advisable to take higher reference field values for low frequencies.

The field strength can be read off from each of the graphs as a function of the distance. It is shown by the unbroken curve designated by the letter E with index E or F according to whether the method of propagation envisaged is made by the E layer or the F layer. The first four components of the field (each one designated by a figure showing the number of ionospheric reflections, with a letter showing the layer on which reflections are made) appear also.

2.2.1 *Comments on Figs. 1 (a) and 1 (b).*

For a total radiated power of 1 kW, Fig. 1 (a) shows the field strength furnished, as a function of distance, by a half-wave doublet 0.25 of a wave-length high, propagated by the F layer at 2000 hours LMT, that is to say, after the sun has set and the layers E and D have disappeared. Hence absorption has been ignored.

Fig. 1 (b) shows the field produced in the same circumstances by a four-slot antenna at the same height.

The effect of antenna gain, and the advantages offered by vertically directive antennae for tropical broadcasting, will be seen at once. The field is intense within the area less than five hundred miles round the transmitter, while being low beyond. Thus the interference that might be caused at long ranges is kept to a minimum.

2.2.2 *Comments on Figs. 2 (a) and 2 (b).*

These graphs show the effect, for a particular type of antenna, of the inclination from the vertical of the transmitter antenna lobe. Once again, we are dealing with F layer propagation at 2000 hours LMT. Fig. 2 (a) represents the field of an antenna with a single slot at a height of 0.25 the wave-length, transmitting vertically. Fig. 2 (b) shows that of a single-slot antenna, at a height of 0.4 times the wave-length, and hence offering, on either side of the vertical, a lobe inclined at about 25°.

It will be seen that when the area close to the transmitter is served by a medium-wave transmitter, it might be well to have an antenna height equal to 0.4 times the wave-length, without there being an increased risk of interference in the area above 800 km (500 miles) from the transmitter.

2.2.3 *Comments on Figs. 3 (a) and 3 (b).*

These graphs show the advantages of E-layer reflection in comparison with F-layer reflection for a particular antenna, by day, allowance being made for absorption. In E-layer propagation, the field is relatively more intense at short distances than in F-layer propagation, while it falls off faster for greater distances. The antenna used in both cases is made up of a half-wave doublet in a horizontal plane at a height of 0.25 times the wave-length above ground. The moment considered, for each graph, is 0800 hours LMT, in June ($R = 10$). The frequency is 5 Mc/s. Note that F-layer propagation, shown in Fig. 3 (b) can be considered normal, whereas the E-layer propagation in Fig. 3 (a) occurs only when the critical frequency of the sporadic-E layer reaches 5 Mc/s.

* In India it has been found that a much higher field strength is required to give a satisfactory service.

2.2.4 Comments on Graphs Figs. 4 (a) and 4 (b).

These two graphs were drawn up for a half-wave antenna at a height of 0.25 times the wave-length, by day. In both cases, the field is produced by F-layer reflection, but in Fig. 4 (a) there is but little absorption, while in Fig. 4 (b), absorption is very great.

It will be seen at once that advantage can to some extent be taken of absorption to get better broadcasting conditions, provided always that very great powers are used and a relatively low frequency. In this fashion, we can do without special antennae with narrow vertical beams, since, in this particular instance, a simple horizontal half-wave 0.25 times the wave-length above the ground will do perfectly well. The field shown in Fig. 4 (b) is produced almost entirely by a single F-layer reflection, so that, in this instance, the quality of the transmission will approach that of medium-wave broadcasting, except very close to the transmitter where the ground wave interferes with the sky wave.

3. Doc. XII/7 (India).

This document is a report on further measurements on ionospheric absorption, some of which were reported earlier in documents at the VIIth and VIIIth Plenary Assemblies. Graphs are presented showing the variation of the monthly means of mid-day absorption and sunspot number over the period September 1954 to October 1957. In another graph the 12-month running averages, of absorption values are plotted against the 12-month running averages of sunspot numbers for the period March 1955 to April 1957 giving practically a linear relationship. A third graph shows the relationship between seasonal variation of absorption and sunspot activity. The following conclusions are drawn:

- The average value of the diurnal variation factor n is 0.62.
- The sunspot cycle variation factor works out at 0.0017. The conclusion is rather tentative and will have to be confirmed from data over a larger number of years. However, the figure is significantly lower than those assumed in the C.R.P.L. and S.P.I.M. formulae.
- The seasonal variation factor may be expressed in the form $|\log \rho| = \text{Const.} (\cos \chi_{\varphi=0})^m$. No attempt has been made to evaluate the value of m as the data are for a period when there was considerable variation in sunspot activity.
- There is appreciable absorption at night.

3.1 Mid-day values of absorption and sunspot activity.

The monthly mean values of mid-day absorption on 5 Mc/s have been plotted in Fig. 5. The mean sunspot number for each month has also been shown in the same figure.

In order more clearly to bring out the dependence of absorption on sunspot activity, the twelve month running averages of absorption values were plotted against the twelve month running averages of sunspot numbers in Fig. 6.

3.2 Seasonal variation of absorption.

In order to investigate the seasonal variation of absorption, the mid-day $|\log_e \rho|$ values have been plotted in Fig. 7 against $\cos \chi$ on a log-log scale.

4. Conclusions.

While significant progress has been made towards the development of a fully satisfactory method of calculating the field strength produced by a tropical broadcasting transmitter, further study is needed before a Recommendation can be made. Administrations are requested to continue their studies, and in particular to test the method of calculation developed by W. R. Piggott, given in the publication referred to under Doc. XII/2 of Geneva, 1958.

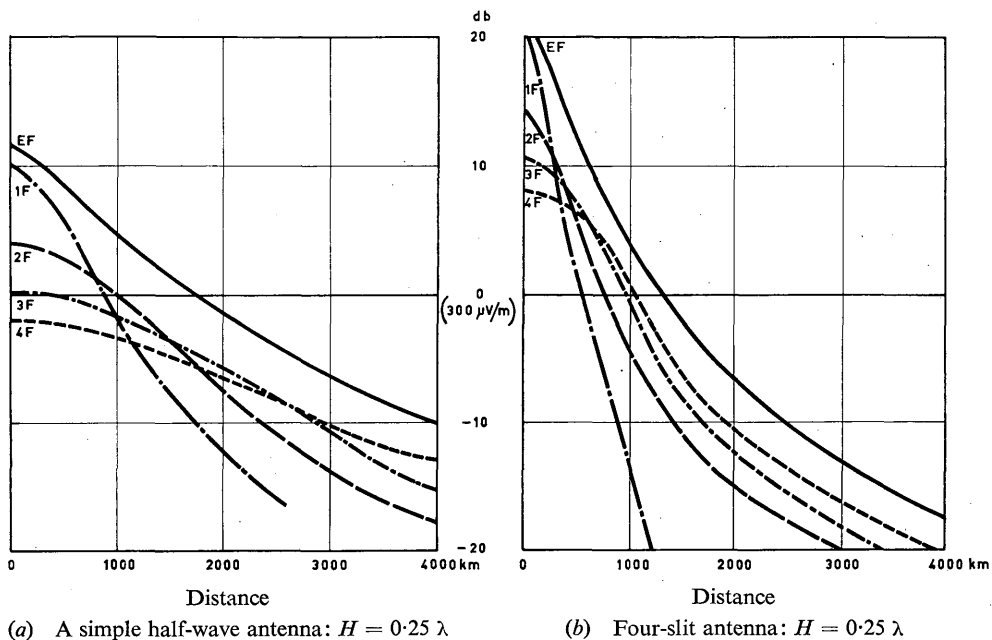


FIGURE 1

Influence of antenna gain for radiation towards the vertical — Dakar, at 2000 hrs L.M.T.

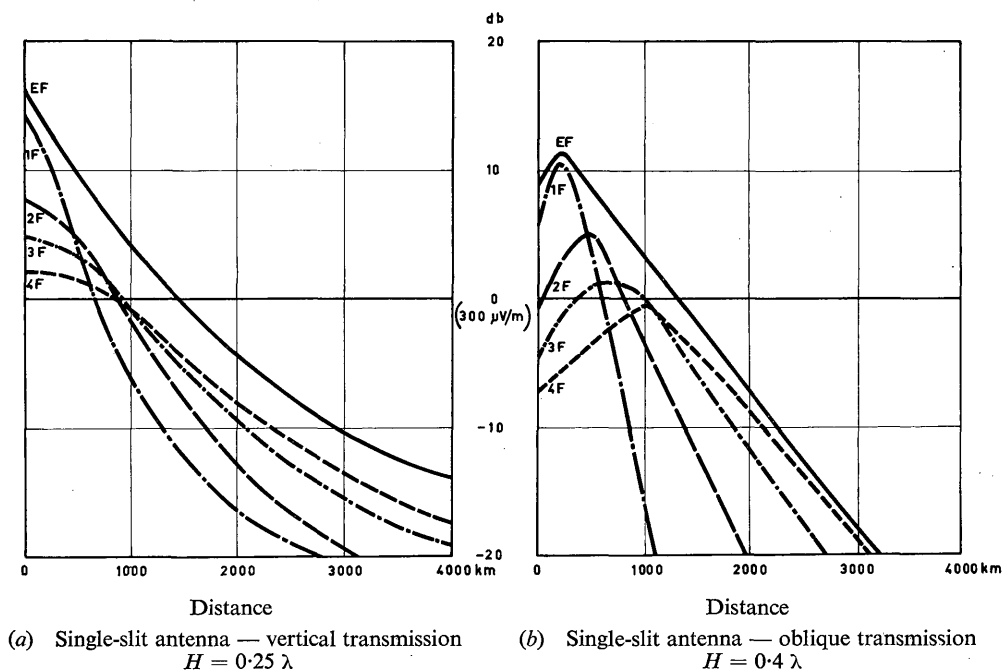


FIGURE 2

The effect of angle of elevation for narrow-beam antennae — Dakar, 2000 hrs L.M.T.

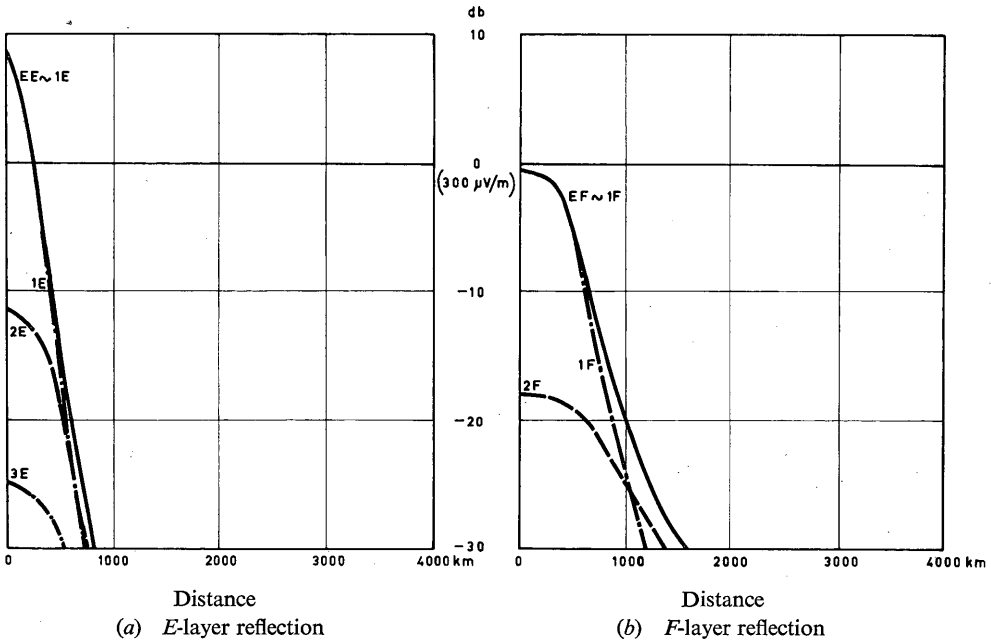


FIGURE 3

Comparison between E-layer and F-layer reflections — Dakar, 5 Mc/s, June, 10, 0800 hrs L.M.T.
Comparable absorption for a half-wave antenna $H = 0.25 \lambda$

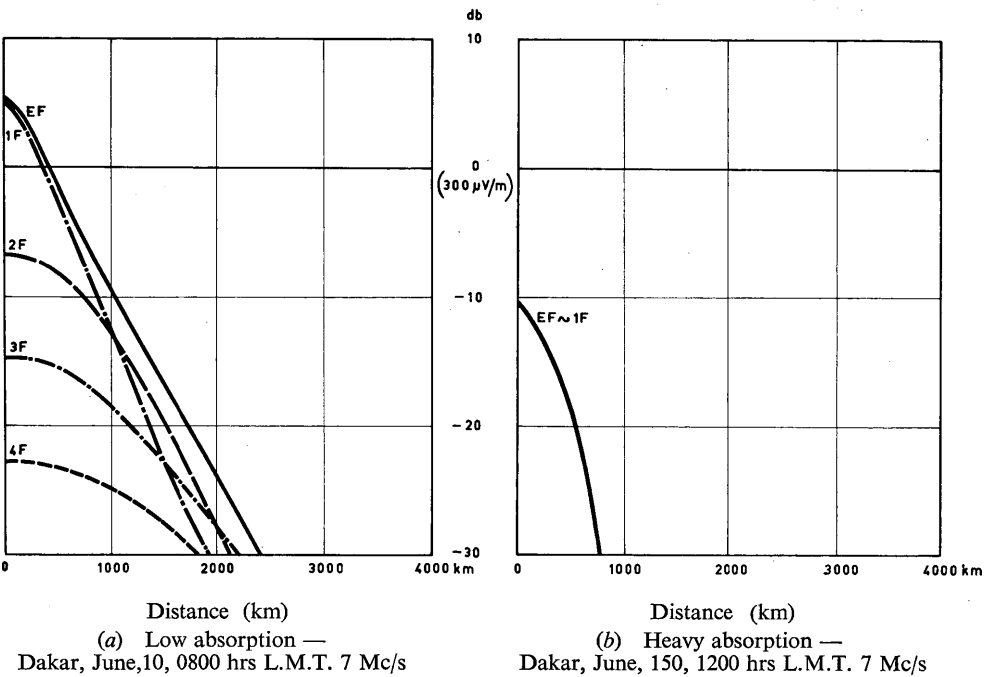


FIGURE 4

The effect of absorption — Half-wave antenna, $H = 0.25 \lambda$

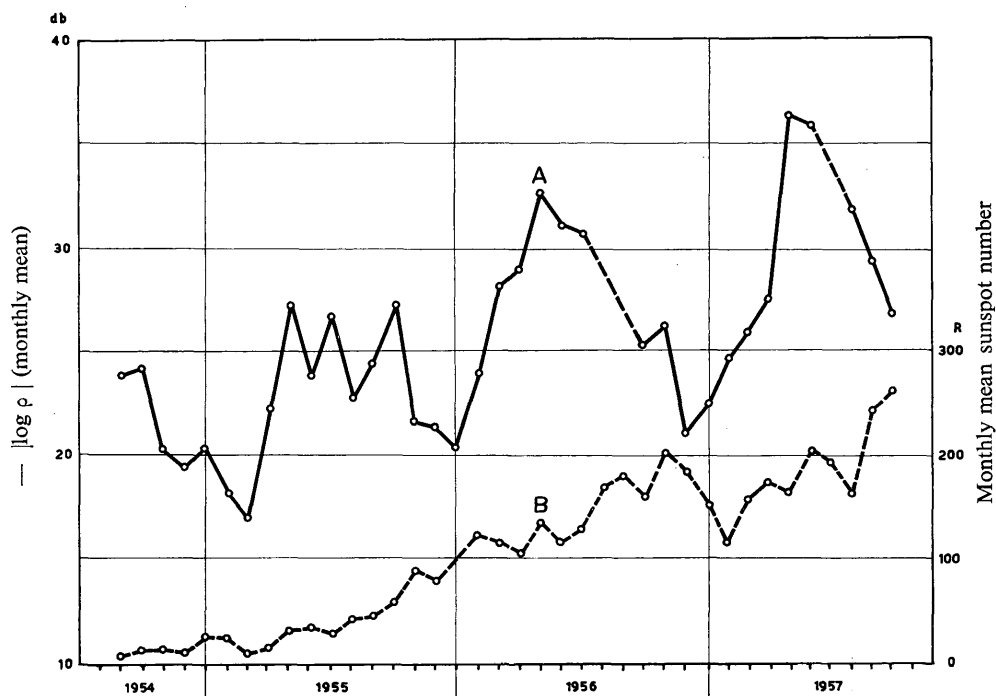


FIGURE 5

Variation of $|\log \rho|$ (A) and R (B) from Sept. 1954 to Oct. 1957

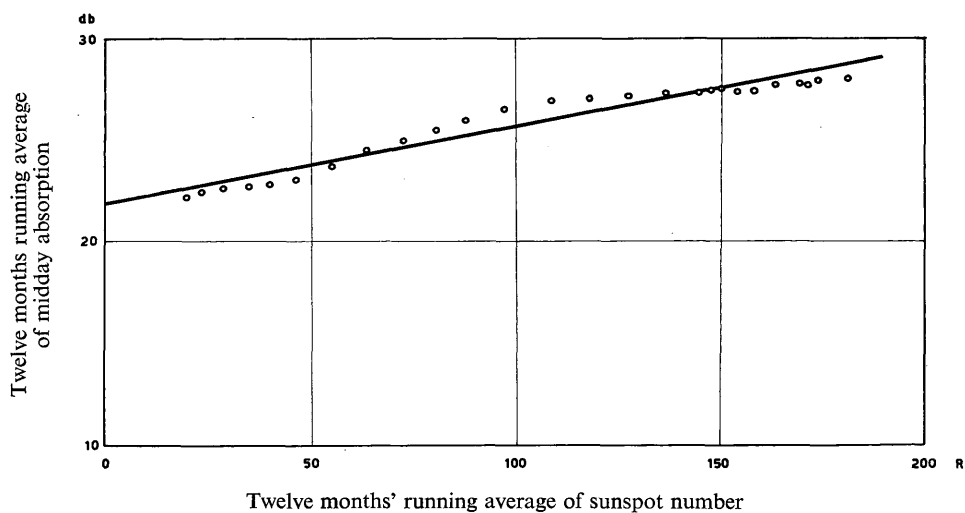
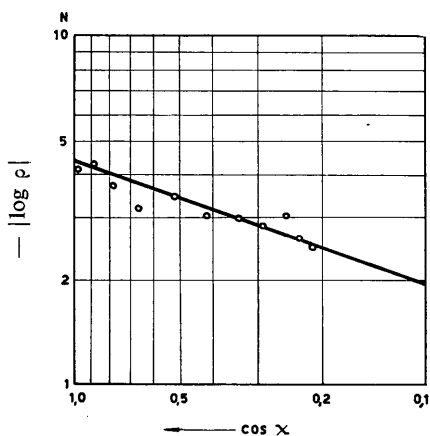


FIGURE 6

Twelve months' running average of midday absorption shown against twelve months' running average of sunspot numbers between March 1955 to April 1957



Seasonal variation of $-\log |\rho|$
 Monthly averages between October 1956 and September 1957

FIGURE 7

REPORT No. 174 *

HIGH-FREQUENCY BROADCASTING BANDWIDTH OF EMISSIONS

(Stockholm, 1948 — Warsaw, 1956 — Los Angeles, 1959)

Listening tests have been made in connection with this investigation on the quality obtainable on short-wave and the effect of reducing the frequency band occupied. From the tests made it is considered that, although there will be some loss in audio-frequency quality in restricting the highest modulating frequency to 6400 c/s, the loss is not serious. Tests have also been made in further restricting the band of frequencies to 5000 c/s. The loss of quality in this further restriction is quite noticeable.

The principal causes of unsatisfactory reception of short-wave signals in decreasing order of importance are considered to be:

- fading and particularly selective fading resulting in heavy distortion,
- insufficient signal/noise ratio at the receiving point,
- heterodynes between carrier frequencies,
- heterodynes between sidebands of different stations or between a sideband of one station and the carrier of another, due to sideband frequencies being transmitted.

In the last case it has sometimes been found that the actual difficulties arise more from harmonics and spurious radiations generated during the process of modulation at the transmitter than from the actual fundamental modulating-frequency components themselves. Of the above causes the first two are outside the scope of the present question. The third cause will be eliminated when all stations move to fully planned frequency allocations, while in the case of the fourth cause, a considerable amount of remedy is in the hands of the listener, who can usually so restrict the bandpass characteristics of his receiver as to eliminate or reduce interference.

* This Report replaces Recommendation No. 28. The P.R. of Albania did not accept Recommendation No. 28, and the P.R. of Poland reserved its opinion on it.

It would be regrettable to eliminate desirable frequency bands from transmissions unless clearly necessary and effective in eliminating interference in particular cases.

The conclusion reached is that it is desirable to maintain the normal bandwidth of modulating frequencies at an upper limit of 6400 c/s.

In order to make bandwidth restrictions as effective as possible, steps should be taken to minimize the radiation of harmonic and intermodulation products in the transmitter and to avoid overmodulation with its inherent production of spurious frequencies.

To consider in some detail the effect in a receiver, the interfering signal is assumed to be a high-frequency broadcasting double-sideband signal with modulating frequencies up to and including 6400 c/s, and with the carrier 10 kc/s removed from the desired carrier. The out-of-band radiation (distortion) of the high-frequency broadcasting signal shall not exceed 5%, and thus the out-of-band radiation falling within the band of the desired signal will be approximately 32 db below the level of the undesired carrier.

The receiver to be considered is the type in general use by the public. Comparison of a number of such receivers has indicated an average selectivity curve which will apply both to European and American receivers, and most employ a diode for demodulation. The average selectivity curve of such a receiver indicates that a signal 10 kc/s removed from the centre of the pass band (assumed position of the desired carrier) will be attenuated 24.4 db. The curve further shows that a signal 5 kc/s removed will be attenuated 8 db, and a signal 3.6 kc/s removed (6.4 kc/s sideband) will be attenuated 5.1 db.

Before considering the actual interference reproduced by the receiver it should be noted that the relatively simple problem of a carrier and two sidebands demodulated by a diode becomes a complex problem when only one sideband reaches the diode or when the amplitude or phase of the carrier and sidebands is altered. Of primary importance to this problem is the further fact that when a carrier is present at the diode, if another carrier is also applied at a lower level, the resultant output is less than either signal. This effect may be analysed by the use of Bessel functions indicating that as the ratio of desired to undesired input to the diode is increased the ratio of desired to undesired output increases much more rapidly.

Assuming no pre-emphasis at the transmitter, and a ratio of desired to undesired signal of 1, the average receiver would admit a 5 kc/s undesired signal to the diode 22.2 db below the desired carrier. Similarly, the 6.4 kc/s interfering sideband would be 21.1 db below the desired carrier and the undesired diode output signal would be more than 40 db below the desired output signal at 100% modulation. The exact value of the diode output is complicated by the fact that the diode linearity varies with input signal and that, in most cases, the diode load varies with audio frequency. However, at desired-to-undesired signal ratios of one or greater, and without pre-emphasis, interference should not be caused.

If receivers are improved, and a much lower ratio of desired-to-undesired signal is then adopted, a point will be reached where interference will be caused by the part of the interfering signal which lies within the receiver pass band.

It has been shown that under usual circumstances the amplitude of the interference should not be troublesome. It may be further noted that the interfering signal will usually beat with the desired carrier and therefore be inverted, the 6400 c/s modulation becoming 3600 c/s interference. The interfering signal would not be intelligible to the listener, and it has been shown that such interference is more easily tolerated than intelligible interference.

At the present time there is no evidence that interference will be caused to the average receiver due to the transmission of normal signal intensities in those portions of the sidebands 5 to 6.4 kc/s removed from the carrier. It does not appear that a reduction in the desired-to-undesired signal ratio will change this conclusion with respect to present receivers. However, the use of pre-emphasis, more selective receivers and modified signal ratios, or a combination of these, may cause the transmission of energy at modulating frequencies up to 5000 c/s and 6400 c/s respectively to assume new importance.

SECTION F

RADIO-RELAY SYSTEMS

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REPORT No. 129 *

**RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION
MULTIPLEX****Methods for the computation of intermodulation noise due to non-linearity**

(Question No. 115)

(Study Group No. IX)

(Warsaw, 1956 — Los Angeles, 1959)

The subject of intermodulation distortion in frequency-modulated radio relay systems carrying multi-channel telephone signals has been studied and attention is called to the following documents which contain valuable reference material:

Doc. No. 29 (U.S.S.R.) of Geneva, 1954. The calculation of non-linear distortion in FDM radio-relay systems with frequency modulation.

Doc. No. 193 (France) of Warsaw, 1956. Methods for the computation of intermodulation noise due to non-linearity in radio-relay systems.

Doc. No. 268 (Netherlands) of Warsaw, 1956. Methods for the computation of intermodulation noise due to non-linearity in radio relay systems.

Doc. No. 388 (Federal German Republic) of Warsaw, 1956. Methods for the calculation of distortion noise due to non-linearity in radio-relay systems.

Doc. No. 407 (U.S.S.R.) of Warsaw, 1956. Non-linear distortion due to multi-path propagation and mismatching of antenna wave-guides in FM multi-channel systems.

Doc. No. 444 (Federal German Republic) of Warsaw, 1956. Demands on the linearity of multi-channel radio link systems with frequency modulation.

Doc. 464 (U.S.A.) of Warsaw, 1956. Methods for the computation of intermodulation noise due to non-linearity in radio relay systems.

Doc. No. 743 (U.S.S.R.) of Warsaw, 1956. Intermodulation noise in radio-relay links.

These documents indicate a very large measure of agreement in the final results, whether the computation is made directly from analysis of the spectrum or indirectly from the correlation function, since the latter is Fourier transformed from the former.

The methods given for computing the intermodulation noise due to the circuit elements at each station are approximations. Nevertheless, the results of experiments are in good agreement with these calculations and the latter may be useful.

It does not appear feasible at this time to formulate precise methods for computing the intermodulation noise due to the circuit elements at each station. Reliance is placed instead on experience with particular types of radio relay systems and their circuit elements to estimate performance from the intermodulation noise standpoint. Apart from such estimates, intermodulation noise on complete systems and certain portions of systems can be determined by measurement techniques.

* This Report which replaces Report No. 74, was adopted by correspondence without reservation (see page 9).

Concerning the addition of noise due to various circuit elements, random noise adds on a "power" basis. Intermodulation noise in practice usually adds in a manner somewhat between "power" and "voltage" addition, as may be seen from the documents listed above.

Note: Resolution No. 57 terminates the study of Question No. 115.

REPORT No. 130 *

RADIO-RELAY SYSTEMS FOR TELEPHONY

Noise tolerable during very short periods of time on line-of-sight systems

(Study Programme No. 158 (IX))

(Los Angeles, 1959)

1. Method of specification.

The maximum values of noise in telephone circuits on radio-relay systems should be specified in terms of:

- the mean psophometric noise in an hour;
- the psophometrically-weighted noise powers which may be exceeded only for specified small percentages of a month when the fading is severe, measured with an instrument which indicates the mean value over one minute or a quantity approximately equivalent to this value.

2. Time constant.

Measurement in terms of the one-minute-mean power is favoured to facilitate the use of the opinion-rating method of assessing telephone conversations recommended by the C.C.I.T.T. Instruments having time constants of one minute are acceptable even though they do not precisely measure one-minute-mean values.

3. Short noise bursts.

Information on the performance of line-of-sight radio-relay links suggests that it is not necessary to specify a limit to the number of high noise bursts of duration exceeding a given value and occurring in a given time, provided that limits are placed on the noise which may be exceeded only for small percentages of a month, and that noise due to power supplies and switching operations is excluded. It is desirable to stipulate in addition that the link should incorporate some form of diversity reception on sections in which the fading is unusually severe, e.g. due to the use of exceptionally long sections or to reflections from a water surface. The Annex gives some information on noise bursts in one country (United States of America); the magnitude and duration of noise bursts in other regions may be somewhat different due to the different meteorological conditions.

* This Report was adopted by correspondence without reservation (see page 9).

4. Traffic loading.

It is recognized that the period of worst fading usually occurs at night, while the greatest traffic often occurs during the day. Whether advantage can be taken of this fact depends on the requirements that the system is intended to satisfy.

5. Noise in parts of radio links.

The noise power during substantial percentages of the time can, without great error, be considered proportional to the length of the circuit, for lengths exceeding about 250 kilometres. There is some reason for assuming that intermodulation noise increases more rapidly with length than does basic noise, nevertheless for lengths of circuit exceeding about 250 kilometres, the error in assuming that noise for substantial percentages of time is proportional to length is small, and it is proposed, therefore, to make use of this law of proportionality in C.C.I.R. Recommendations.

When considering very small percentages of time for which high noise values may be exceeded, these percentages can be considered as proportional to circuit length for lengths of circuit exceeding 250 kilometres and for values below 0.1% or in some cases below 1%.

The two working rules given above, i.e. linear-power-addition for large percentages of time and linear-percentage-addition for small percentages of time, are somewhat inaccurate between about 0.1% and 10% where the error may in extreme cases amount to 3 or 4 db. However, the rules are considered to be sufficiently accurate for most purposes. Greater accuracy can be obtained by detailed mathematical treatment which depends upon the particular monthly distribution curves involved. A method of approximation which can give useful accuracy in some cases has been discussed by B. B. Jacobsen (Proc. I.E.E., Part C, March 1958).

ANNEX

RELATIONSHIP BETWEEN SHORT-TERM AND LONG-TERM NOISE PERFORMANCE IN RADIO-RELAY SYSTEMS IN THE UNITED STATES OF AMERICA

1. The distribution of the duration of deep fades (and hence the resulting noise bursts) at the frequencies used in radio-relay systems appears to be log-normal. Such a distribution may be characterized by:

- its slope or its standard deviation, and
- one point on the curve, such as the median or the average duration.

2. From several series of tests, the standard deviation is approximately $\log_{10} 2.7$, and appears to be substantially independent of frequency. This standard deviation has been observed in tests on individual paths and on systems comprising as many as 68 paths in tandem. It has been observed at different frequencies from 2000 to 6000 Mc/s. It has been observed in different regions which are subject to different fading influences and on paths with both adequate and inadequate clearance. A somewhat higher standard deviation appears to be associated with inadequate clearance, possibly because of an increased tendency towards obstruction fading.

The average duration is not as closely defined, and appears to be approximately inversely proportional to frequency. That is to say, at a given depth of fade at 2000 Mc/s half as many fades twice as long as at 4000 Mc/s would be expected. The total time of fading would be nearly the same, although this is only approximately true over frequency ranges greater than 2 to 1.

At 4000 Mc/s an average duration in the order of 7 to 9 seconds has been observed for 30 db fades and in the order of 4 to 5 seconds for 40 db fades, in a limited series of tests on a system composed of 40 km paths.

The duration of fades is approximately inversely proportional to the length of the radio frequency paths. The data quoted were observed on a system composed of paths approximately 40 km long in the North-Eastern United States of America. In other tests on paths approximately 70 km long in the Western United States of America, durations approximately 40/70 as long were observed.

3. From these points it is possible to relate the number and duration of the fades to the total time that a given depth of fade is exceeded in a long period of time, such as a month.

4. As a further example, consider a 4000 Mc/s system with parameters such that a 40 db fade in any one section will cause the noise to exceed a given maximum level. Consider further that each section may be expected to fade 40 db or more for n seconds during the worst month * and consider that there are N sections in tandem, without diversity, so that the total time that a 40 db fade will be exceeded somewhere in the system ** is nN seconds during the worst month.

5. From § 2 and 4, the system of the example might be expected to experience $nN/4.5$ or $0.22 nN$ fades exceeding 40 db during the worst month. The duration of these fades would be as outlined in § 2.

6. Fading differs from day to day and from hour to hour. The worst day will have more fades than an average day by some variable factor, and the worst hour will have more fades than the average hour by some still more variable factor. In one series of tests on a system 450 km long including 8 paths, the first factor was 6 and the second factor was 60. There is no information for other lengths of systems or other numbers of paths.

7. The system of the example might, therefore, be expected to experience

$$\left(\frac{1}{30} \times 6\right) \times 0.22 nN = 0.044 nN$$

fades during the worst day of the worst month, and

$$\left(\frac{1}{30} \times \frac{1}{24} \times 60\right) \times 0.22 nN = 0.018 nN$$

fades during the worst hour of the worst month.

8. If the performance of a specified system is predicted using the methods of the example, it may be found that the performance does not meet the requirements of Recommendation No 287. This demonstrates the need for avoiding the effects of fading by

- diversity operation,
- reducing the length of paths or the choice of more favourable sites,
- improving the fading margin by the use of higher power or higher gain antennae where these factors are at the disposal of the system designer.

9. The effects of deep fades may be substantially reduced by the use of some form of diversity reception, such as frequency diversity or space diversity. A limited series of tests has shown that approximately 5% of the total fading time beyond 40 db cannot be counteracted by frequency diversity of 100 Mc/s or more by vertical space diversity of 15 metres or more at 4000 Mc/s. The duration of the residual fades with diversity may be shorter than without diversity, by as much as 50%. No information is available on this point.

* For the North-Eastern United States and for paths about 40 km long, n may be taken as approximately 100. In other areas, and for other lengths of path, different values of n may be appropriate.

** The probability that 40 db fades will occur simultaneously in more than one of the N sections is very small. For shallower fades such as, 20 db, the probability of simultaneous fades is greater and may be appreciable.

10. With the foregoing as guidance as to the probable performance of a system during the worst hour and worst day of the worst month, it is sufficient to define the system by the long-term performance, i.e. the statistical distribution of noise during the worst month.

REPORT No. 131 *

**RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION
MULTIPLEX**

Technical characteristics to be specified in order to interconnect any two systems

(Question No. 192 (IX))

(Warsaw, 1956 — Los Angeles, 1959)

1. Introduction.

This Report is concerned with Part 1 of Question No. 93, that is, the preferred characteristics of radio relay systems using frequency-division multiplex (FDM) which it is proposed to specify and the reasons why such specification is considered necessary.

The systems under consideration are those in which the input and output signals, i.e. the "baseband" signals, consist of an assembly of suppressed-carrier single-sideband telephone signals in channels spaced 4 kc/s apart, using arrangements of channels recommended by the C.C.I.T.T.

It is assumed that the FDM signals themselves modulate the frequency or the phase of a radio-frequency carrier; other possible methods exist, e.g., the modulation of a sub-carrier by the FDM signal which, in turn, modulates the radio-frequency carrier, but such methods will not be considered further in this Report.

The specification of certain preferred characteristics of FDM radio relay systems forming part of an international circuit is necessary in order to permit the ready interconnection of different radio relay systems; the specification of some of these characteristics is also necessary to permit the ready interconnection of FDM radio relay system with FDM line systems.

2. Stages at which the interconnection of radio relay systems among themselves or with line systems may be required.

The interconnection of different radio relay systems at national boundaries may be required at:

- baseband frequencies,
- intermediate frequencies,
- radio frequencies.

The interconnection of radio relay systems at baseband frequencies may be essential in some cases in order to permit the extraction or insertion of individual channels, groups or super-groups of channels, and it may also be necessary for level regulating, monitoring, supervisory or control

* This Report which replaces Report No. 71, was adopted by correspondence without reservation (see page 9).

purposes. The interconnection of radio relay and line systems will normally be carried out at baseband frequencies, since the possibility of interconnection at the intermediate or radio frequencies does not exist in such cases.

The interconnection of radio relay systems at intermediate frequency enables the additional noise and distortion due to demodulation and remodulation to be avoided; it also reduces the amount of equipment required as compared with interconnection at baseband frequencies. It should be noted that interconnection at the intermediate frequency requires the specification of the baseband signal, as well as the modulation characteristics, i.e., the deviation of the intermediate-frequency carrier. Interconnection of two radio relay systems at intermediate frequency is, of course, more readily carried out if the two intermediate frequencies are the same; nevertheless, the possibility exists of translating from one intermediate frequency to another if need be, but it should be borne in mind that difficulties may arise if the two intermediate-frequency bands overlap.

However, the need for a preferred spacing between the radio frequency channels (discussed below) makes it necessary to adopt a value for the intermediate frequency, such that interference in the working channels from the frequency-change oscillators of receivers and repeaters is avoided. This requirement, together with the need to facilitate interconnection at intermediate frequency, makes it desirable to adopt a preferred value for the intermediate frequency.

The interconnection of two radio-relay systems at radio-frequencies may be needed when crossing a boundary between two countries where the topography is such that a common frontier station is impracticable or undesirable, as for example, when the boundary is located in a wide river estuary or a sea channel between the two countries. In such cases there must be agreement on the radio frequencies themselves, as well as on the modulation characteristics of the radio-frequency carriers and on the baseband signal. This in turn necessitates agreement on the spacings between, and the arrangements of, the radio-frequency channels. The adoption of preferred values for the spacing and arrangement of the radio-frequency channels has the advantages of economising in the use of the frequency spectrum and of minimising interference between radio relay systems whose routes intersect or are in close proximity.

3. Characteristics to be specified for international connections.

It is assumed that overall performance of the telephone channels should, as far as possible, be in accordance with the relevant C.C.I.T.T. recommendations for modern types of telephone circuit (C.C.I.R. Recommendations Nos. 40 and 268).

Where international connections are involved, agreement on the characteristics listed below and marked by the sign †, is considered essential; agreement on the remaining characteristics, although not essential, is considered highly desirable in order to make possible interconnection in the most economical and effective manner.

As standardization is not yet possible, it is suggested that preferred values should be indicated for the guidance of those concerned with the specification and design of radio relay systems.

The characteristics for which preferred values should be given are listed below according to whether they relate to interconnection at the baseband, intermediate or radio frequencies.

3.1 *For interconnection at baseband frequencies:*

3.1.1† maximum number of telephone traffic channels;

3.1.2† highest and lowest frequencies of telephone traffic channels, i.e. the frequency limits of the baseband; it is assumed that the arrangement of the telephone channels is in accordance with C.C.I.T.T. recommendations;

3.1.3 nominal impedance of baseband circuits at the point of interconnection;

3.1.4 relative input and output power levels at the point of interconnection.*

* The choice and precise definition of a point of international interconnection is a subject for agreement between the administrations concerned.

In addition to the above, consideration will need to be given to the monitoring, control or supervisory signals transmitted with the traffic channels.

3.2 *For interconnection at intermediate frequencies :*

For interconnection at intermediate frequencies it will be necessary to give preferred values for the baseband characteristics 3.1.1 and 3.1.2, in addition to the following characteristics:

3.2.1† centre value of the intermediate frequency *; because of the wide range of radio frequencies and numbers of channels that may be employed, it may be necessary to give more than one preferred value for the intermediate frequency; the number of intermediate frequencies should, however, be no more than is essential to meet the various requirements;

3.2.2† the frequency deviation of the carrier caused by a tone of 1mW applied to a channel at a point of zero relative level in the system; in systems with a large number of telephone channels, e.g., 600, it may be found desirable to use pre-emphasis, producing a larger deviation for the higher frequency channels to improve the signal-to-noise ratio; if this is so, it will be necessary to specify the amount of pre-emphasis to be employed at the various channel frequencies;

3.2.3 input and output levels of the intermediate-frequency signal at the point of interconnection;

3.2.4 impedance of the intermediate-frequency circuit at the point of interconnection.

3.3 *For interconnection at radio-frequencies :*

For interconnection at radio frequencies it will be necessary to give preferred values for the baseband characteristics 3.1.1 and 3.1.2 and the frequency deviation 3.2.2, in addition to the following characteristics:

3.3.1† number and arrangement of the radio-frequency channels;

3.3.2 wave polarization.

Interconnection at radio-frequencies also requires that the frequency stability of the transmissions employed shall be within certain tolerances. Reference should be made to Recommendation No. 233.

* In the case of multi-channel telephony systems, the centre value of the intermediate frequency corresponds to the unmodulated carrier frequency.

REPORT No. 132 *

**RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY DIVISION
MULTIPLEX****Design objectives for voice-frequency (V.F.) telegraphy on telephone channels**

(Question No. 192 (IX))

(Los Angeles, 1959)

1. Extracts from the Report of the Joint C.C.I.T.T.-C.C.I.R. Working Party on Circuit Noise.

The C.C.I.T.T.-C.C.I.R. Joint Working Party on Circuit Noise has proposed (in C.C.I.T.T. Document Com. 1 No. 94) a further recommendation on the allowable noise in telephone channels to be used for the transmission of VF telegraph signals. This proposed recommendation is:

“If the use is foreseen of V.F. telegraphy equipment conforming with the recommendations of Series B of the C.C.I.T. in order to obtain the quality of transmission recommended in Recommendation No. F.7 of the C.C.I.T. Violet Book, the mean unweighted noise power over 5 ms shall not exceed 10^6 pW for more than 0.001% of any month, and 0.1% of any hour.”

Annex 2 of the same document states:

“The design objective as regards errors caused by noise in telegraph transmission can be taken as one error in 100 000 characters in a telegraph channel on a 2 500 km hypothetical reference circuit for telephony. Noise surges reaching powers exceeding 200 000 pW are liable to cause a significant number of errors in telegraph transmission. The error rate produced by a given noise power depends on various factors such as the distortion already existing in the telegraph connection. Allowance has been made for the uncertainties regarding these various sources of distortion in arriving at the design objectives for noise;

10^6 pW (unweighted) computed in a telephone channel at a zero relative level point with an integrating time of 5 ms not to be exceeded for more than 0.001% of any month and for more than 0.1% of any hour.

Little information is available on the performance of radio-relay systems in small percentages of the time such as 0.001% of the month, and 0.1% of an hour. It would be necessary for tests to be of several years' duration in order to take account of seasonal and other variations, and to assemble sufficient data. It is possible that some existing radio-relay systems already meet the above design objectives. In other cases it may be difficult to attain the desired objectives unless special methods are adopted, for example, the use of diversity reception or the placing of radio stations closer together.”

2. Comments by the C.C.I.R.

The design objectives proposed by the C.C.I.T.T. for noise in telephone channels used for VF telegraphy represent a higher standard of performance than is necessary for the transmission

* This Report was adopted by correspondence without reservation (see page 9).

of telephone speech and signalling. It is doubtful if existing radio-relay links attain the design objectives for VF telegraphy, particularly as regards the requirements for one hour of any month.

It is undesirable for economic reasons that radio links should be designed on the basis of the noise performance in a small proportion of any hour. If a period of a few years is considered, there will in general be one hour having a much worse performance than the remainder of the hours, and it would clearly be an uneconomic basis of design if the radio system were to be called upon to satisfy a high standard of performance even in this one hour.

It is recognised, however, that from the point of view of the telegraph service it is undesirable that there should be too great a concentration of telegraph errors in certain hours. It is thought that this can be taken into account in the design of radio-relay systems without introducing a specific design objective in terms of small percentages of any hour. Designers should take due note of the requirements for an error rate of 1 in 100 000 characters. A statement regarding the frequency of occurrence and the duration of high noise peaks due to fading is given in Report No. 130.

As regards the proposed noise objective of 10^6 pW (with 5 ms integrating time) not to be exceeded in more than 0.001% of any month, it is noted that allowance has been made for various uncertainties in arriving at this proposal.

Many radio-relay links are required to provide a large number of telephone channels of which only a few are intended for VF telegraphy transmission. In these circumstances it may often be desirable for economic reasons to use the design objectives for telephony and to take special measures if necessary to attain a very high standard of telegraph transmission. Among the special measures which are possible, as alternatives to those mentioned above, are:

2.1 the simultaneous transmission of the telegraph signals over two telephone channels with appropriate combining networks at the ends. The telephone channels may be in different broadband channels on the same radio-relay link, or they may follow different routings, provided that these have substantially the same transmission delay.

2.2 the use of particular telephone channels specially chosen as being less subject to high noise surges due to fading, than the majority of the telephone channels.

2.3. the use of special methods of voice-frequency telegraph transmission, such as those mentioned in Annex 2 of the C.C.I.T.T.-C.C.I.R. Joint Working Party Report (C.C.I.T.T. Doc. Com. 1 No. 94), such as:

- suitable modulation processes
- reduction in the number of telegraph channels, thus allowing an increase in the signal level per channel
- use of automatic error-correcting systems.

3. Typical noise distribution curves.

The C.C.I.R. (Study Group IX) has constructed some distribution curves of noise with time in a 2500 km hypothetical reference circuit for line of sight radio links with adequate clearance. The curves have been based on measured values of the received signal in the worst month in a two year period in the various repeater sections of a 400 km radio-relay link having eight repeater sections and operating on 4000 Mc/s in the United Kingdom. The curves are in broad agreement with the statements made in the Annex of Report No. 130 regarding fading in the United States of America.

Two distribution curves, *A* and *B* are shown in Fig. 1. Curve *A* relates to thermal noise in a hypothetical circuit consisting of 16 repeater sections with severe fading, 16 repeater sections with moderate fading, and 16 repeater sections with slight fading*. Curve *B* is the estimated performance of the same link assuming that diversity reception is used.** The measured data was in terms of a time constant of about one second; this is appropriate for the given circumstances, as pointed out below (§ 5). The mean noise power per repeater section in the absence of fading has been taken as -78dbm0 .

The curves *A* and *B* are to be compared with those submitted by the C.C.I.T.T.-C.C.I.R. Joint Working Party on Circuit Noise, (Annex 3 of C.C.I.T.T. Document Com. 1 No. 94). They resemble curves 3 and 4 of the C.C.I.T.T. document rather than curves 1 and 2. However, in view of the possibility that some links might be constructed having different path lengths resulting in curves similar to 1 and 2, it is suggested that telegraph experts be asked to study the effects of all the curves 1, 2, 3 and 4.

4. Numbers and durations of noise bursts.

The attention of the C.C.I.T.T.-C.C.I.R. Working Party on Circuit Noise is drawn to the Annex of Report No. 130 which gives information on the numbers and durations of noise surges due to fading in the United States of America. It appears likely that the envelope of a typical noise surge may be approximated by a rectangular shape, with steep almost vertical sides and a rounded or nearly flat top. The durations of such noise surges is usually a few seconds (e.g. 4 seconds) at a height corresponding to a fade of about 40 db; the duration does not vary much over a considerable range of heights. This envelope is that of the noise power averaged over the fine fluctuations of the white noise; a more detailed "picture" would show standard white noise fluctuations modulated in amplitude by the nearly rectangular fades.

The total durations of such noise surges in various ranges of noise levels in the worst month, corresponding with the distribution curves *A* and *B*, are given in Table I.

The estimated numbers of noise surges of various levels are also given in Table I; the estimates are based on the surge durations of 4 to 9 seconds suggested by the Annex of Report No. 130.

There is insufficient information available to enable the table to be extended for higher noise powers. It is clear, however, that for noise powers of the order of -30dbm0 (10^6 pW) the total duration in the worst month would be appreciably smaller than the values 780 secs for curve *A* and 78 seconds for curve *B* shown for -38dbm0 . The average duration of surges would be somewhat smaller than the value of 4 seconds taken for -38dbm0 ; the number of surges of duration less than one second would be small.

5. Time constant of the measuring instrument.

If the "model" (§ 4) of a typical noise surge is accepted as satisfactory, a suitable time constant of a measuring instrument could be about one second. Alternatively, if it were desired to take some account of the fluctuations of the fine structure of the white noise, a time constant of about 5 ms might be appropriate. However, the difference between the measurements obtained with time constants of about 1 second and with about 5 ms is likely to be very small and it seems likely that the measurements of received signal strengths on various radio links already made with a time constant of about one second, will give a very good indication of the noise performance as it affects telegraphy. These remarks apply only to line-of-sight radio links with adequate clearance.

* It is not justifiable to extend curve *A* for shorter percentages of the time.

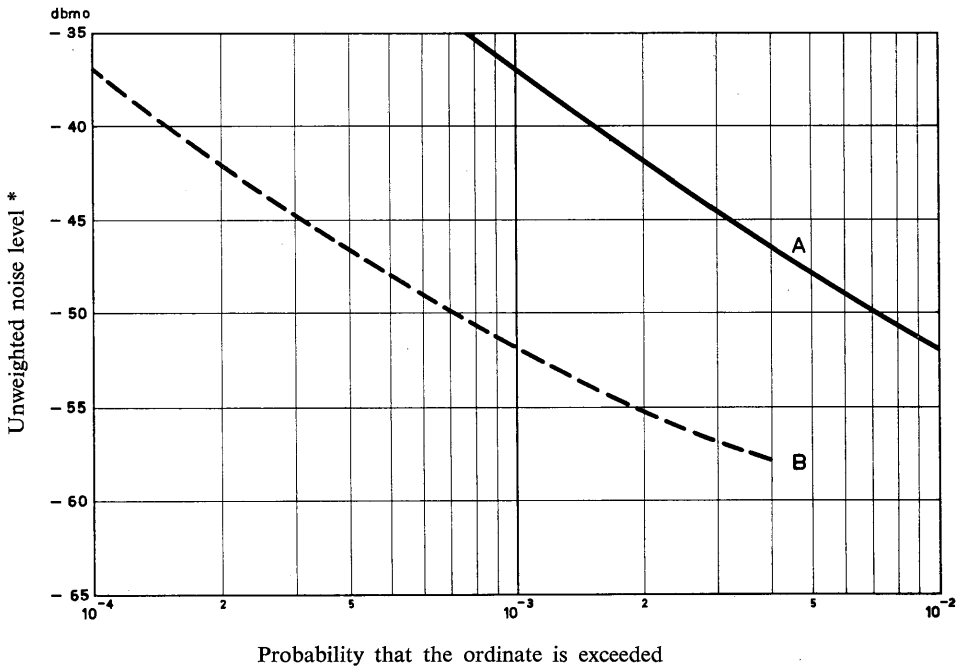
** In some cases a performance similar to that of curve *B* might be obtained without using diversity reception.

If a noise surge is applied to a telegraph filter of bandwidth about 100 c/s, the effect will be to shape the rise and fall of the noise surge. The rise time and fall time cannot be less than the reciprocal of the bandwidth, e.g. about 10 ms.

TABLE I
Numbers and durations of noise surges
(In agreement with curves A and B of Fig. 1)

Mean noise power in 3.1 kc/s band (dbm0)	Total durations <i>T</i> (sec) and estimated numbers <i>N</i> of noise surges at the given noise power range in worst month			
	Curve A		Curve B	
	<i>T</i>	<i>N</i>	<i>T</i>	<i>N</i>
- 37 to - 39	780	195	78	19
- 39 to - 41	1040	216	104	21
- 41 to - 43	1560	280	156	28
- 43 to - 45	2050	320	205	32
- 45 to - 47	2820	392	282	39
- 47 to - 49	4160	520	416	52
- 49 to - 51	6500	738	650	73

Note: The telegraph circuit may be imagined to be exposed to a steady white noise of mean power - 38 dbm0 (- 40 dbm0) of total duration 780 seconds (1040 sec.) divided into 195, 216 etc., occurrences lasting between 4 and 9 seconds, for Curve A.



Probability that the ordinate is exceeded
Noise distribution (worst month) for 2500 km radio-relay link assuming the fading conditions stated in § 3

* Time constant about 1 second.

REPORT No. 133 *

RADIO-RELAY SYSTEMS FOR TELEVISION AND TELEPHONY**Alternative transmission of telephony and television**

(Question No. 194 (IX))

(Warsaw, 1956 — Los Angeles, 1959)

It is considered that substantial economic and operational advantages may be realised in certain cases by using the same radio relay system for the *alternative* transmission of multi-channel telephony and television on the same radio-frequency carrier. These advantages are likely to accrue under the following conditions:

- where the “ busy-hours ” for telephony and the need for television transmission occur at different times of the day;
- where several radio-frequency channels are provided on a route and it is desired to provide a spare channel which can be used as required for either telephony or television; the spare channel may also be used for “ special event ” television broadcasts not justifying the provision of a regular channel;
- where it is desired to provide a flexible network offering the possibility of alternative routes in the event of a major breakdown.

Since the transmission requirements are similar in many respects, it is practicable to use frequency-modulation radio-relay systems for the alternative transmission of television signals or frequency-division multiplex telephony with up to 1 800 telephone channels. However, it should be noted that:

- the transmission characteristics of the common equipment (aerials, feeders, radio-frequency and intermediate-frequency filters and amplifiers) must meet the more stringent of the requirements for television on the one hand, or for telephony on the other hand;
- in any case, the essential technical characteristics for the relaying of multi-channel telephony and television signals should, wherever practicable, be chosen in such a manner that the use of the greatest number of similar or common units is made possible, the costs being thereby reduced.

* This Report which replaces Report No. 69, was adopted by correspondence without reservation (see page 9).

REPORT No. 134 *

**RADIO RELAY SYSTEMS FOR TELEPHONY USING TIME-DIVISION
MULTIPLEX****Technical characteristics to be specified in order to be able to interconnect
any two systems**

(Question No. 92)

(Study Group No. IX)

(Warsaw, 1956 — Los Angeles, 1959)

1. General.

There are a number of different forms of TDM system in use or under consideration. Of those in service the majority use pulse position modulation, combined with amplitude modulation of the radio carrier (PPM-AM). However, PPM systems with frequency modulation of the radio carrier (PPM-FM) are also used, as are systems with pulse amplitude modulation combined with frequency modulation of the radio carrier (PAM-FM).

Different numbers of speech channels are provided by various systems; other systems again provide for telegraph channels, good quality music channels or other forms of traffic, either specifically or as alternatives to speech channels. Still further systems transmit by time division groups of speech channels which are themselves assembled by frequency-division multiplex.

Systems using pulse code modulation are not covered by this report.

From the point of view of international interconnection, TDM systems can, in this report, be divided conveniently into those using pulse position modulation and those using pulse amplitude modulation. Systems of one type can be interconnected with the other, or with FDM radio relay links or landlines, at audio frequency, and recommendations regarding this are given in Recommendations Nos. 40 and 297.

Interconnection at baseband (by which is meant here the sequence of modulated pulses before application to the radio carrier), at intermediate frequency or at radio frequency requires the two systems concerned to be of the same type (both PPM or both PAM) and that the specifications of certain parameters should be co-ordinated.

Section 2 of this report lists those parameters requiring specification for baseband interconnection, while § 3 gives the *additional* parameters for intermediate-frequency interconnection. Intermediate-frequency interconnection is not normally used for PPM-AM systems, but could be appropriate for systems using frequency modulation of the radio carrier.

* This Report which replaces Report No. 70, was adopted unanimously.

Where international interconnection at radio frequency is more appropriate, it is considered that at present the co-ordination of the necessary technical parameters should be the subject of direct agreement between the administrations concerned.

To render unnecessary any specific agreement regarding the characteristics of the supervisory system, it is suggested that in an international connection between a TDM radio relay system and a second telecommunication system (either similar or different), both supervisory systems should terminate at or near the international boundary, or that the method of interconnection should be the subject of agreement between the administrations concerned.

A service channel is considered necessary as part of a TDM radio relay system and this service channel should be accessible at all repeater stations.

2. Technical characteristics to be specified for baseband interconnection of any two TDM systems using pulse position modulation or of any two TDM systems using pulse amplitude modulation.

A. Characteristics applicable to both PPM and PAM systems.

2.1 Audio channel characteristics.

- 2.2** — maximum number of telephone traffic channels;
— maximum number and type of traffic channels for other types of service, e.g., music, telegraphy, facsimile, groups of telephone channels assembled in FDM.

2.3 Number of equal time intervals in a sequence.

2.4 Channel sampling rate:

- for telephone traffic,
- for other types of service.

2.5 Pulse polarity at the point of interconnection.

2.6 Impedance characteristics and resulting reflection effects at the point of interconnection.

2.7 Characteristics of synchronizing signal (or marker signals (if any)) at the point of interconnection.

2.8 Characteristics and position of service channel, if included in the baseband.

2.9 Characteristics of any special signals sent over the system.

2.10 Type and characteristics of commander, if used.

2.11 Special requirements, if any, for the insertion and dropping of channels and blocks of channels.

B. Characteristics applicable to PPM systems only.

2.12 Width and shape of channel pulses at point of interconnection.

2.13 Significant characteristics of pulse.

2.14 Peak to peak excursion of the channel pulse, without commanders, for standard modulation *.

2.15 Input and output pulse amplitudes at the point of interconnection.

* *Note* : By "standard modulation" is meant modulation by an 800 c/s signal of 1 mW at a point of zero relative level, or the equivalent signal for music or for other types of service.

C. Characteristics applicable to PAM systems only.

2.16 Width and shape of channel pulses at point of interconnection:

- with zero modulation,
- with standard modulation *.

2.17 Input and output amplitudes of the channel pulse at the point of interconnection, with zero modulation.

2.18 Maximum and minimum amplitude of the channel pulse (without companders) at the point of interconnection, for standard modulation *.

Co-ordination of all the above parameters is necessary at stations where channels are demodulated. At those repeater stations where channels are not demodulated, it is only necessary for the following characteristics to be co-ordinated:

for PPM, the characteristics given in § 2.5, 2.6, 2.12 and 2.15;

for PAM, the characteristics given in § 2.5, 2.6, 2.16, 2.17, and 2.18.

3. Technical characteristics additional to those listed in § 2 above, to be specified for interconnection at intermediate frequency of any two TDM systems using pulse position modulation or of any two TDM systems using pulse amplitude modulation.

3.1 Centre value of the intermediate frequency.

3.2 The frequency deviation of the carrier and, if necessary, the sense of deviation (if frequency modulation is used), for standard modulation as defined in § 2 of this report.

3.3 Input and output levels of the intermediate-frequency signal at the point of interconnection.

3.4 Impedance characteristics and resulting reflection effects at the point of interconnection.

4. Present position regarding the recommendation of specific values for the parameters listed in § 2.

At present it has not been found possible to reach such agreement on these parameters as to make interconnection possible between any two different PPM or any two different PAM systems other than at audio frequency, and where such cases arise they should be dealt with in the manner indicated in Recommendation No. 306.

There has, however, been a general agreement on certain points, particularly concerning PPM systems. These agreed points are, therefore, listed below under the paragraph numbers used in § 2.

2.1 Audio channel characteristics.

For telephone circuits reference is made to Recommendation No. 297.

2.2 (a) Maximum number of telephone traffic channels.

To achieve maximum economy in interconnection with other systems, particularly FDM radio relay systems and line systems, it is highly desirable to provide telephone traffic channels in groups of 12.

* Note: By "standard modulation" is meant modulation by an 800 c/s signal of 1 mW at a point of zero relative level, or the equivalent signal for music or for other types of service.

2.4 *Channel sampling rate for telephone traffic.*

The preferred value of channel sampling rate is 8 kc/s with a tolerance of ± 8 c/s or better. Unless otherwise agreed between the administrations concerned, the pulse trains may be separately generated for the two directions of transmission.

2.5 *Pulse polarity at point of interconnection.*

For PPM systems positive polarity is preferred.

2.6 *Impedance characteristics and resulting reflection effects at the point of interconnection.*

The preferred nominal value of the impedance at the point of interconnection is 75 ohms.

2.12 } *Width and shape of channel pulses at point of interconnection.*
2.16 }

Attention is drawn to the need to use pulse shapes requiring the minimum bandwidth consistent with the facilities given by the system.

2.16 *Grouping of channels using marker signal synchronization.*

If marker signals are used, it is possible to assign to each group of 12 channels an individual marker signal as this will enable the other groups to continue to function properly when one or several groups suffer a break-down, and will also facilitate the branching-off of groups.

2.15 *Input and output pulse amplitudes at the point of interconnection in PPM systems.*

The preferred value of the pulse amplitude at a point of international interconnection is 1.4 V at the output from the receiving equipment and 0.7 V at the input to the transmitting equipment. The difference in level allows for loss in the means of interconnection.

REPORT No. 135 *

**RADIO RELAY SYSTEMS USING TROPOSPHERIC OR IONOSPHERIC
FORWARD-SCATTER**

Reply to Question No. 11 of the 3rd Study Group of the C.C.I.T.T.

(Study Group No. IX)

(Los Angeles, 1959)

QUESTION NO. 11 READS:

1. Can a hypothetical reference circuit be specified relating to circuits which use propagation by tropospheric or ionospheric forward scatter ?

If so, what should be the composition of this circuit and the mean psophometric power at the end of a 2500 km line ?

2. What should be in actual service, the statistical distribution as a function of time of the signal-to-noise ratio of telephone circuits set up on these links ?

* This Report was adopted by correspondence without reservation (see page 9).

3. In actual service, what should be the statistical distribution as a function of time, of transmission breaks on such links:

- (a) resulting from equipment failures ?
- (b) from power supply failures ?
- (c) from propagation failures ?

4. How many carrier telephone circuits and how many telegraph systems could be provided by these systems and what should be the division of the frequency spectrum at the input and output terminals ?

5. What multiplexing technique should be recommended on radio links of this type and how should the telephone circuits be assembled at the input and output terminals ?

6. For what purposes should these systems be used ?

THE ANSWER IS:

The C.C.I.R. is of the opinion that ionospheric forward-scatter systems are not likely to attain the transmission performance recommended by the C.C.I.T.T. for international telephone circuits on metallic conductors. Moreover it is not aware of any proposals for incorporating such systems in the telephone network. Therefore, the C.C.I.R. feels it to be appropriate to exclude these systems from the answer to Question No. 11 of the 3rd Study Group of the C.C.I.T.T. and to deal only with tropospheric-scatter radio links.

The proposed replies to the different parts of the Question are :

Part 1.

1.1 As tropospheric-scatter radio-relay systems may form a part of an international circuit, it seems desirable, as for other transmission systems, to have a hypothetical reference circuit as a guide to designers. An effort to formulate such a circuit should be made, even if at first it is incomplete due to the limited experience available at present.

1.2 As for other hypothetical reference circuits, an overall length of 2500 km is proposed. It does not however appear possible, at the present state of the art and with existing experience, to propose a detailed subdivision into homogeneous sections, because the length of the radio sections between stations may vary within wide limits, e.g. between 100 and 400 km. It appears that in such systems, interconnection between the radio sections will usually be made at baseband frequencies.

1.3 From what is known about tropospheric scatter systems, it appears to be possible to meet the performance recommendations for line-of-sight radio-relay systems substantially, at least so far as mean noise power is concerned, i.e. 7500 pW mean psophometric power in any hour at the end of a 2500 km hypothetical reference circuit, as defined in § 1 of Recommendation No. 292. For international circuits it is important to maintain such performance standards in all possible cases.

The attaining of this desirable objective may, however, in some cases in the present state of the art, result in excessive or even prohibitive cost, impracticably high power or such power as might result in undesirable interference; this might prevent desirable extensions of the telephone network.

It is therefore recommended that the opinion of the C.C.I.T.T.-C.C.I.R. Joint Working Party on Noise be sought regarding a suitable performance recommendation for these cases; until such a recommendation is available it is proposed to recommend provisionally a performance similar to that adopted by the C.C.I.T.T. for open-wire lines.*

* For open-wire lines, according to Vol. 1 of the Red Book of the C.C.I.T.T. (Question No. 38 of the 1st Study Group, and Annex, page 290) a mean psophometric power of 20 000 pW at zero relative level should not be exceeded at the end of a 2500 km circuit; this value applying to the mean noise power in the busy hour during periods when the line is not subjected to very unfavourable climatic conditions (which corresponds probably to at least 90% of the time).

In such cases (after subtraction of 2500 pW for multiplex equipment) the mean psophometric noise power at the end of a 2500 km hypothetical reference circuit should not exceed 17 500 pW at zero relative level; this value applies to the mean noise power in any hour, except during the periods when the link is subjected to very unfavourable propagation conditions (it is expected that in most cases this would correspond to very much less than 10% of the time, but this aspect remains open for further study).

Part 2.

Insufficient experience is available on the statistical distribution of the noise power as a function of time on real tropospheric scatter circuits to make a proposal. However, on international circuits the objective should be to conform as closely as is practicable with the requirement of § 1 of Recommendation No. 292.

It is recommended that this part of the Question should also be studied by the C.C.I.T.T.-C.C.I.R. Joint Working Party on Noise.

Part 3.

3.1 It is the opinion of the C.C.I.R. that transmission interruptions due to power supply and equipment failures depend solely on the engineering practice applied to the equipment design, the grade of maintenance available and the expense that can be justified for power plant. Insufficient information exists to enable any reply to be made to this point and the C.C.I.R. is doubtful whether this study is likely to produce useful results.

3.2 Concerning transmission interruptions due to propagation phenomena, insufficient data are available at present on fading and Study Group No. V of the C.C.I.R. is studying this matter.

Parts 4 and 5.

At present it seems to be unlikely that more than 120 telephone channels will be transmitted on most tropospheric scatter radio link systems and 12 to 60 telephone channel systems are expected to be more common.

VF telegraphy can be used on tropospheric radio links, and in such cases it is expected that one telephone channel in twenty-four may be used as a bearer channel for this purpose; in practice up to about 12 telegraph channels have been used on one telephone channel. However, the performance requirements for channels used as bearer channels for multichannel VF telegraphy may be different from those which would be essential if the same channels were used only for telephony.

Baseband characteristics and multiplexing techniques should follow standard C.C.I.T.T. practices. Recommendation No. 269 refers.

Part 6.

From what is known on the subject, the application of tropospheric radio link systems will be especially appropriate where for geographical or other reasons other transmission means seem to be uneconomical or cannot be used, e.g. for the bridging of longer over-water distances or communication within less densely populated regions.

These systems are normally used for telephony and telegraphy, with relatively small channel capacity as indicated above, but this type of link has also been used for television.

REPORT No. 136 *

RADIO-RELAY SYSTEMS USING TROPOSPHERIC-SCATTER PROPAGATION

Radio-frequency channel arrangements for systems using frequency modulation

(Study Programme No. 122 (IX), Question No. 196 (IX))

(Los Angeles, 1959)

1. Introduction.

Study Programme No. 122 (IX) asks for a study of radio-frequency channel arrangements for tropospheric-scatter radio-relay systems. The studies carried out so far give valuable information on the problems to be taken into account for establishing such a radio-frequency channel arrangement usable over a wide geographical area. Since the technique of using radio-relay systems on tropospheric-scatter links is not yet fully developed, the results obtained do not yet allow an agreement on a preferred frequency arrangement for such systems but may serve as a guide in planning the frequency arrangements for systems that might be established in the near future.

2. Considerations on which a radio-frequency channel arrangement for tropospheric-scatter radio-relay systems might be based.

2.1 The high radiated power of tropospheric-scatter systems and the long range of tropospheric-scatter propagation may give rise to serious interference at distances extending beyond international boundaries, for example 1000 km;

2.2 Interference both between and within tropospheric-scatter systems can be minimised by the co-ordination of radio-frequency channel arrangements over a large geographical area;

2.3 Many interfering effects between equipments at the same station can be minimised by a carefully planned arrangement of radio frequencies;

2.4 Radio-frequency channel arrangements should provide for various capacities of FDM telephony (e.g. from 12 to 300 telephone channels) and for television;

2.5 With the frequency deviations likely to be employed the bandwidth of the emission may range from a fraction of 1 Mc/s for a few telephone channels, to 8 Mc/s or more for television;

2.6 To avoid undue interference between stations the minimum distance separating a receiving station from a transmitting station operating on the same frequency may have to be large, for example 1000 km or more depending on the power used and the orientations and polarizations of the antennae;

2.7 A useful reduction in the distance within which a station represents a potential source of interference is possible if the stations operate on frequencies which are slightly different, the

* This Report was adopted by correspondence without reservation (see page 9).

minimum useful separation being of the order of 0.8 Mc/s for the narrower band frequency modulation systems (see Annex I) or perhaps for future single-side band amplitude modulation systems;

2.8 Different frequency allocations are discussed for tropospheric-scatter radio-relay systems, e.g. within two bands of 20 Mc/s, separated by a gap of 60 Mc/s and within a continuous band about 130 Mc/s to 200 Mc/s wide;

3. Technically feasible radio-frequency channel arrangements for frequency-modulation systems based on the above considerations.

3.1 A basic pattern of the radio-frequency channel arrangements is proposed with a unit separation of 0.8 Mc/s, the spacings between the frequency allocations used in a given system or geographical area being integral multiples of 0.8 Mc/s;

3.2 At any station the minimum separation between transmitters could be 7 units (5.6 Mc/s); for systems with more than 36 channel capacity greater separation may be necessary;

3.3 The minimum separation of transmitters and receivers at any station should be about 50 Mc/s, but in any case an integral multiple of 0.8 Mc/s should be chosen; in some cases an appreciably greater spacing might be required in order to ensure that the necessary attenuation is obtained between the transmitter output and the receiver input;

3.4 For two 20 Mc/s bands separated by 60 Mc/s, the arrangement of the radio-frequency channels could be as shown in Plan *A*, Fig. 1;

3.5 Where a single band of up to 200 Mc/s is available, the arrangement of the radio-frequency channels could be as shown in Plan *B*, Fig. 2;

3.6 Plan *A* would, in general, be used for low-capacity FDM telephony systems; it is therefore based on a unit spacing of 0.8 Mc/s. An example of the application of Plan *A* is shown in Fig. 1 (*b*);

3.7 Plan *B* could be used for both low-and high-capacity FDM telephony and possibly for television; in the latter cases, the minimum spacing of radio-frequency allocations at one station might be several integral multiples of 5.6 Mc/s, say two (11.2 Mc/s) for 60 channels, three (16.8 Mc/s) for 120 channels and five (28 Mc/s) for television. Examples of the application of Plan *B* are shown in Fig. 2 (*b*);

3.8 Where several links are connected in tandem to form a longer route, a suitable allocation of frequencies to ensure maximum spacing between adjacent station frequencies would be in the order, 1, 5, 2, 6, 3, 7, 4, 1, etc. (as shown in Fig. 2 (*b*));

3.9 In order to avoid interference within a station the spacing of the transmit and receive frequencies should not be chosen near to the first IF of the receiver, i.e. not near to 35 or 70 Mc/s in cases where the IF corresponds to the preferred values given in Recommendation No. 273.

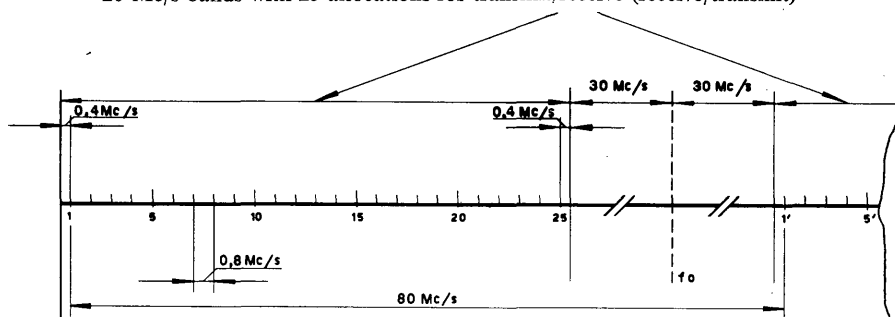
ANNEX

INTERFERENCE BETWEEN ADJACENT RADIO-FREQUENCY CHANNELS OF FM, F.D.M. RADIO-RELAY SYSTEMS

The interference due to an unwanted modulated carrier at or near the wanted carrier frequency will depend upon the deviation which is being used. However, it will be clear that even for large deviations the interference falls as the carriers are separated by more than a few hundred kc/s.

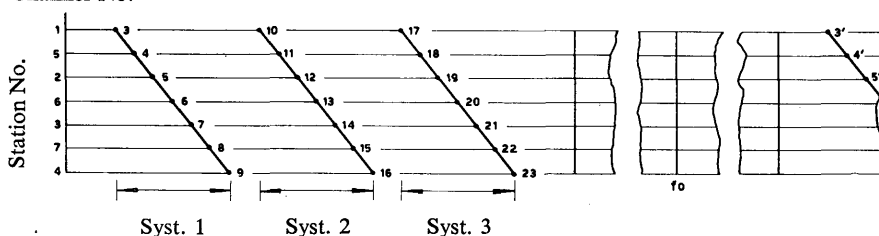
In view of the wide area over which a tropospheric scatter signal can cause interference, and the relatively slow decay with distance of the scattered signal (say, 10 db at 100 km (60 miles)), it is preferable to stagger frequencies by a small amount rather than re-use them exactly.

20 Mc/s bands with 25 allocations for transmit/receive (receive/transmit)



(a) Basic pattern of radio-frequency channel arrangement

Channel No.

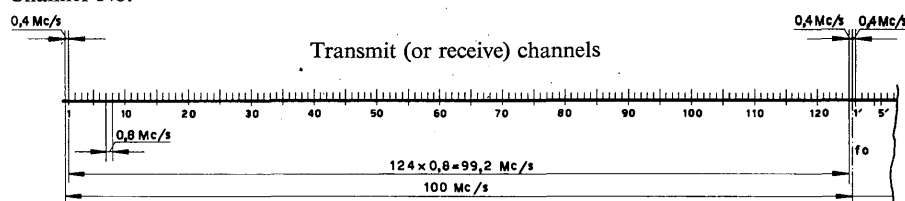


(b) Example of application to three multi-hop telephony systems in the same geographical area (the frequency allocations shown along each inclined line are used on different hops of each system and are not necessarily in numerical order)

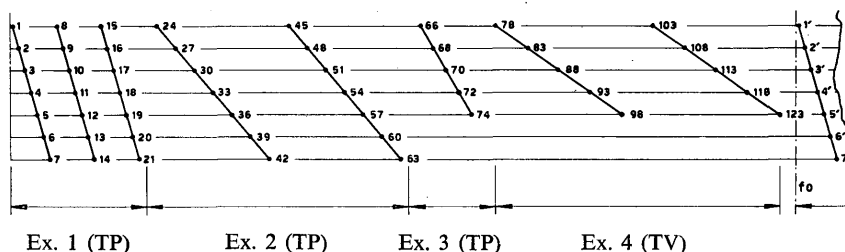
FIGURE 1

Radio-frequency channel arrangements for tropospheric-scatter propagation systems (Plan A)

Channel No.



(a) Basic pattern of radio-frequency channel arrangement for transmit (or receive) in one half of band: similar arrangement for receive (or transmit) in other half.



(b) Examples of application to telephony systems of various bandwidths and to television in the same geographical area

Note: In each example, the frequencies shown along one horizontal line may, if desired, be used for transmitters (or receivers) at the same station provided that the bandwidths of filtering arrangements are appropriate.

FIGURE 2

Radio-frequency channel arrangements for tropospheric-scatter propagation systems (Plan B)

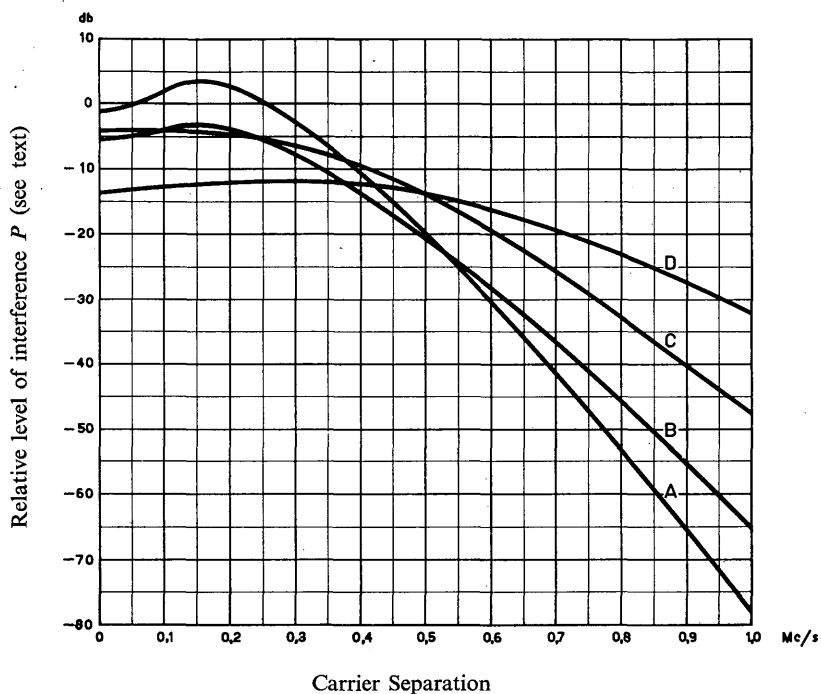


FIGURE 3

Variation of interference with carrier frequency spacing

- A — Deviation 37 kc/s r.m.s.
- B — Deviation 48 kc/s r.m.s.
- C — Deviation 66 kc/s r.m.s.
- D — Deviation 91 kc/s r.m.s.

The attached curves (Fig. 3) show the way in which the interference changes as two carriers, each modulated with 36 channels FDM (12—156 kc/s), are separated. Four deviations are shown, 37 *, 48 **, 66 * and 91 ** kc/s r.m.s. per channel. There is no significance in these particular deviations; the values arise from scaling from existing data on other bandwidths or deviations.

From the curves it is felt that a stagger frequency of 800 kc/s would show a worthwhile advantage for all likely deviations and this figure is therefore recommended.

The actual interference signal ratio in the top channel of the wanted transmission is given by $(P + 20 \log_{10} r)$ db where r is the relative amplitude of the unwanted carrier, expressed as the voltage ratio and P is given by the curves.

* Scaled from MEDHURST, HICKS and GROSSET, *Proc. I.E.E.*, 105, Pt. B, p. 282, (May, 1958).

** Scaled from HAMER and ACTON, *Electrical and Radio Engineer*, 34, p. 246, (July, 1957).

REPORT No. 137 *

**DURATION OF INTERRUPTIONS ON RADIO LINKS WHEN SWITCHING
FROM NORMAL TO STAND-BY EQUIPMENT**

(Question No. 197 (IX))

(Los Angeles, 1959)

1. Protection of radio-relay channels against interruptions due either to failure of equipment or to deep fading is usually supplied by automatically switched protection channels. Three general types of automatic switching arrangements are currently in use for the purpose. They are:

1.1 Multi-line switching, in which one protection channel serves two or more normal channels;

1.2 Single-line switching, in which one protection channel serves one normal channel;

1.3 Combining, in which the outputs of two parallel channels are combined at base-band or at intermediate frequency.

The specified requirements for time of operation of the three types differ; in general, the systems are required to operate as fast as the state of the art permits.

2. Two types of interruption are recognized:

2.1 the *transfer time* of the switch element itself, which while operating may introduce a short-circuit, an open-circuit or double transmission, and

2.2 the *operate time* of the entire automatic switching system, from the instant that transmission is degraded sufficiently that switching is desirable to the instant that service is restored by completion of switching to the protection channel.

The specified limit for duration of an interruption of the first type is set by telegraph transmission, where interruptions of less than 1 ms will not cause errors on 50-baud a.m. or f.m. VF (carrier) telegraphy. (It is also necessary to consider the level changes and phase changes associated with switching from one circuit to another, since these also can cause telegraph errors.) There is already a demand for data circuits which operate at much higher speed than 50-baud VF (carrier) telegraphy, and consequently, it is considered desirable to find means of reducing the switching interruption time considerably below 1 ms.

3. There appears to be no hope, of reducing the operate time of the entire switching system for to 1 ms. The various components of the total operate time are, for multi-line switching:

3.1 Time of recognition of fade or failure, at receiving end.

3.2 Time to construct a control signal to be sent to the transmitting end.

* This Report, which was adopted unanimously, does not cover interruptions due to power supply failures; this subject should be studied separately.

- 3.3 Transmission time of control signal to transmitting end.
- 3.4 Recognition time at transmitting end.
- 3.5 Bridging time at transmitting end.
- 3.6 Transmission time of signals over protection line to receiving end.
- 3.7 Time to examine signal received over protection line.
- 3.8 Time to decide whether the switch should be operated.
- 3.9 Actual switch operation time.

4. By the natural laws of propagation, item 3.3 alone is usually 2 ms or more. Considering all the above items, and allowing 5 ms for margin, an objective of 35 ms seems practicable and appears to fulfill the following:

- 4.1 A barely perceptible interruption to voice.
- 4.2 A tolerable interruption to television — noticeable, but very seldom causing a failure of field synchronization.
- 4.3 A noticeable but not severe streak on phototelegraphy.
- 4.4 No seizure of common equipment in toll-dialling offices.

5. The effect of failures on the operate time of the entire automatic switching system will differ from that of fades. Failures usually interrupt transmission completely and suddenly, and service is not restored until the entire operate time has elapsed. With fading, transmission will probably continue to deteriorate but may not completely fail after the instant that request for switching is initiated. If the operate time and the noise level which will cause switching to be requested are properly proportioned to the maximum rate of increase in fading loss, it is possible to eliminate transmission errors due to fading. The maximum increase in fading loss on optical paths has been taken conservatively at 100 db per second, and if the operate time is 33 ms, the fading loss will increase 3 db during the interval between a request for switching and the completion of switching. If there is at least 3 db margin between the noise level causing a request for switching and the noise level that would produce transmission errors, no transmission errors will be caused by the fading, provided of course, that transmission over the protection channel is satisfactory so that switching actually takes place.

6. Single-line switching systems and combining systems operate much faster than multi-line switching systems because the normal and protection channels can be bridged permanently at the transmitting end so that there is no necessity to originate, transmit and recognise control signals. However, single-line switching systems cannot apparently be made fast enough to eliminate errors in 50 baud telegraph and data transmissions. For these services combining arrangements are preferable.

In some cases, standby equipment has been provided which can be switched to replace normal equipment which has failed. Generally, the objective is to complete switching as fast as the state of the art permits.

7. In summary, the following design objectives seem feasible at present:

7.1 *Transfer time* : 1 ms, which appears acceptable for most services; however, if high speed data transmissions are required, and even for certain types of VF (carrier) telegraphy, this value should be considerably reduced.

7.2 *Operate time* : 35 ms, which may cause errors in 50-baud telegraph transmission.

With systems now in service, the transfer time may be about 3 to 5 ms and the operate time may be 50 ms or more.

8. In conclusion, the switching systems must be such that interruptions due to the operate time occur only in case of:

8.1 failure of normal equipment;

and that the interruption is limited to the transfer time in the two other cases:

8.2 failures in radio propagation;

8.3 switching over from normal to protection equipment for maintenance.

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REPORT No. 43 *

REVIEW OF PUBLICATIONS ON PROPAGATION

(Recommendation No. 14)

(Study Group No. V)

(Geneva, 1951 — Warsaw, 1956)

Recommendation No. 14 served to focus attention on the extraordinary amount of effort which is being expended in learning the facts of radio propagation and in applying them to radio operations and to international control and adjustment of the various radio services. This great field of effort is illustrated by the reviews prepared by eleven members in response to Recommendation No. 14, which appear as Annexes ** to Doc. No. 115 of Washington. These reviews in most cases report on the period 1938 to 1948 inclusive. The field of radio propagation was summarised under C.C.I.R. auspices in 1937, covering progress up to that time. The results were given in "Report of Committee on Radio Wave Propagation", which was distributed by the Bureau of the International Telecommunication Union before the 1938 Cairo Conference, and was published in *Proceedings, Institute of Radio Engineers*, 26, pp. 1193-1234 (October, 1938).

Since 1937, work on radio propagation has been exceedingly active and extensive. The phenomena of the ionosphere have been intensively studied and the results increasingly applied to the practical determination of optimum frequencies for long-distance transmission over any transmission path at any time. Propagation via the troposphere has been vigorously explored and much has been learned, particularly regarding propagation at VHF and higher frequencies. Microwave propagation has been pioneered. Ground-wave propagation has been reduced to quantitative calculation.

The publications on radio propagation are scattered through many scientific and engineering periodicals and books. References to these papers are given monthly in the lists of "Abstracts and References" published in *Wireless Engineer* and *Proc. I.R.E.*

It is thus clear that a vast amount of work on radio propagation has been going on and is continuing. This field is now recognised as fundamental to radio operations and engineering. The work in progress is undertaken for a variety of motives and objectives. Some of it is on basic physical phenomena, some directed closely to specific engineering applications, and all of it is of interest.

The extent and value of the work on radio propagation is further illustrated by its extensive use in recent international conferences. Many compilations of methods of using ionospheric propagation data and an extraordinary number of charts have been prepared for and by recent international conferences. These have been indispensable in conference work and will be needed even more in the future. As they were prepared hurriedly to meet specific needs, a valuable service could be rendered by reviewing them and, if necessary, supplementing them.

* This Report replaces Report No. 3.

** The reviews of radio propagation work submitted by various countries appear as the following Annexes to Doc. No. 115 of Washington:

A	Belgium	G	Sweden
B	U.S.A.	H	Switzerland
C	France	I/I	Union of South Africa
D	Italy	K	Netherlands
E	New Zealand	L	Canada
F	United Kingdom		

It is believed that no other worth-while specific guidance "regarding desirable future work" could be given in any overall manner by the C.C.I.R. or any other body. On the other hand, the questions established and the studies made by the C.C.I.R. do provide incentives and objectives which are taken into account by the administrations, companies, research institutes and individuals engaged in radio propagation work. The effect of the C.C.I.R. work as a whole upon the various programmes of radio propagation work will therefore provide the real answers to Recommendation No. 14. The means by which the C.C.I.R. enables the various people in this field to work together is a valuable means of furthering and co-ordinating the work.

The C.C.I.R. Secretariat may be requested to distribute to Study Group chairmen contributions which, in the view of an administration, may be of interest to other administrations on the subject of radio propagation and which may be sent to the C.C.I.R. Secretariat for that purpose.

The choice of new questions and other acts of future Plenary Assemblies will in fact be the "regular recommendations" envisaged in Section B 7 of Recommendation No. 1 adopted by the International Radio Conference, Atlantic City, 1947.

REPORT No. 45 *

EFFECTS OF STANDARD TROPOSPHERIC REFRACTION ON FREQUENCIES BELOW 10 Mc/s

(Study Programme No. 87 (V))

(Warsaw, 1956)

Some work is described in Doc. No. 196 (France) of Warsaw, 1956, in connection with § 1 of Study Programme No. 51 which suggests that the effect of tropospheric refraction is still significant in ground-wave propagation on a frequency of 1554 kc/s at a distance of 230 km over sea.

It is difficult, however, to be certain that the effect of the ionosphere was entirely eliminated, although the experiments were carried out around mid-day. In the report of the Chairman of Study Group No. IV (Doc. No. 104 of Warsaw, 1956) an example is chosen in § 6.3 of Annex I to correspond to the conditions given in Doc. No. 196 of Warsaw, 1956 and a calculation is made of the field-strength based on Bremmer's theory for the inclusion of the troposphere.

The agreement with the experimental results is reasonably good, but in making such a comparison it is really necessary to know what effective radius of the earth should be chosen for the conditions of the experiment.

It is clear, therefore that further work is needed before the question of the effect of the troposphere on propagation on frequencies below 10 Mc/s can be answered even partially by experimental evidence.

From the theoretical angle the problem can be approached by assuming that the refractive index of the atmosphere has a specific form as a function of height, chosen to be amenable to mathematical analysis while corresponding to the real atmosphere in its essential features.

It is clear that the effect of tropospheric refraction is still marked at 10 Mc/s but that its effect is probably negligible at 10 kc/s where the wave-length is large compared with the height above the ground at which the refractive index of the atmosphere ceases to decrease linearly with height. The mathematical analysis should reveal the nature of this transition and provide a method of modifying the propagation curves in Recommendation No. 307 accordingly.

* This Report was adopted unanimously.

When the frequency is made to approach zero the formula given by Bremmer (see the reference in the footnote to Study Programme No. 87 (V)) does not degenerate exactly to the formula for an atmosphere for which the refractive index is everywhere unity, though the residual difference is very small. This formal difference may arise from the fact that, in the model used, the refractive index approaches, at large heights, a value that is about 0.9 instead of unity, as pointed out in Doc. No. 23 (United Kingdom) of Warsaw, 1956.

It appears that at a frequency of 10 kc/s, the difference, using this model, may still be appreciable and it would be interesting to use another model that satisfies the required conditions at the surface of the earth and also at great distances from the earth, assuming that it is amenable to mathematical analysis over the whole frequency range.

The model used by Bremmer is nevertheless probably amply adequate for the study of the transition region between approximately 10 Mc/s and 10 kc/s as is borne out by the calculations made in Annex I of the Chairman's Report (Doc. No. 104 of Warsaw, 1956).

REPORT No. 46 *

TEMPORAL VARIATIONS OF GROUND-WAVE FIELD STRENGTH

(Study Programme No. 52)

(Study Group No. V)

(Warsaw, 1956)

Contributions to this study which were submitted to the VIIIth Plenary Assembly, Warsaw 1956, are summarized below:

Doc. No. 24 (Federal German Republic) deals with a series of measurements made to observe the temporal variations of the field strength of various medium-frequency broadcast transmitters and to observe also the actual variations of the effective electrical constants of the soil. It was concluded that the observed field variations were not caused by variations in effective soil constants since, seasonally, a period of high field values (in winter) occurred at the same time as low values of the soil constants were observed, and vice versa. Some preliminary correlation between the variations of the soil constants and the level of subterranean water was, however, obtained.

Doc. No. 140 (United Kingdom) confirms previous observations which showed high values of field strength in winter months and correspondingly low values during summer months. It is concluded that although changes of conductivity of the soil and absorption due to vegetation could both account for the effects observed, the latter is the more probable explanation.

Doc. No. 182 (France) refers also to measurements reported in Doc. No. 196 (France) which were made over a sea path. The field was found to remain constant within a range of 6 db and showed no seasonal trend.

Doc. No. 220 (F. P. R. of Yugoslavia) presents a discussion on the effect of temperature variations on the soil conductivity and the field strength.

* This Report which replaces Report No. 20 and completes the work of Study Programme No. 52 was adopted unanimously.

Doc. No. 274 (Netherlands) makes two brief references to the temporal variation effect. It was observed in the VHF (metric) band that field strengths in winter were 1 to 2 db higher than in summer over medium distances and that the presence of leaves in summer time increased the absorption.

Note. — The above Report should be brought to the attention of the U.R.S.I. by the Director of the C.C.I.R. with a view to encouraging that organisation to expedite its work bearing on these studies, requesting the U.R.S.I. to inform the C.C.I.R. of the results of its study.

REPORT No. 51 *

INVESTIGATION OF MULTIPATH TRANSMISSION THROUGH THE TROPOSPHERE

(Study Programme 57 (V))

(Warsaw, 1956)

A theoretical investigation has been carried out in Italy on the propagation between two points at the ends of a path which is non-optical for normal atmospheric conditions, taking into account the fact that in Italy a state of super-refraction frequently occurs at heights of less than 500 m above sea level. *Doc. No. 351* of Warsaw, 1956, is an abstract of a published paper ** on this subject, in which it is pointed out that under conditions of super-refraction, the effective curvature of the earth becomes concave, with the result that there may be three points of reflection of the waves transmitted between sender and receiver. Under these conditions the coefficient of divergence is transformed into one of convergence, which, under particular conditions, results in the possibility of a focusing effect of the waves arriving at the receiver. The paper describes the parameters necessary for calculating the field resulting from the interference between the direct ray and the reflected rays with the aid of the abac annexed to *Doc. No. 352* of Warsaw, 1956.

Docs. Nos. 330 and 366 (Japan) of Warsaw, 1956, describe experiments performed with a multi-ray measuring device with a frequency sweep of 3850 ± 250 Mc/s, and also a useful method of extracting the mean signal level and its variance from a mass of observations. It is suggested that statistical values of the amplitude ratio ρ and the path difference l , obtained independently, are not suitable for assessing distortion due to multipath transmission. It is more appropriate to use the product ρl *** in designing microwave multi-channel radio relay systems. If the quantity ρl is known, the amount of distortion due to multipath transmission can be estimated from the magnitude of the fading, which can be easily measured. This deduction was confirmed by the results of experimental tests made during the summer, when multipath transmission was expected to occur most frequently.

Some information relating to § 4 and 5 of the Study Programme has resulted from tests carried out in the United Kingdom using a frequency of 4000 Mc/s on two overseas paths, 58 km and 88 km long respectively. Observations on diversity reception and selective fading were made and the results illustrate some of the effects of multipath transmission on micro-wavelengths.

It is clearly necessary for more extensive investigations to be made on all aspects of this Study Programme and for further tests to be carried out for longer periods and over a variety of paths in different parts of the world.

* This Report was adopted unanimously.

** SACCO, L. II Collegamento Radio in Regime Superrefrazione Atmosferica. *Alta Frequenza*, 6, (December 1955), 436-469.

*** ALBERSCHEIM, W. J. and SCHAFER, J. P. Echo distortion in the FM transmission of frequency-division multiplex. *Proc. I.R.E.*, p. 316, (March 1952).

REPORT No. 65 *

REVISION OF ATMOSPHERIC RADIO NOISE DATA

(Recommendation No. 310)

(Study Programme No. 154 (VI))

(Warsaw, 1956 — Los Angeles, 1959)

1. Introduction.

The determination of the minimum signal level required for satisfactory radio reception in the absence of other undesired radio signals necessitates a knowledge of the noise with which the desired signal must compete at the receiving location. Studies of radio noise levels have been in progress for a number of years.

The initial research leading to the first publication of predictions of world-wide radio noise levels was carried out in 1942 by a group in the United Kingdom at the Interservices Ionosphere Bureau and in the United States at the Interservice Radio Propagation Laboratory [1].

Predictions of world-wide radio noise have been published subsequently in R.P.U. Technical Report No. 5 [2] and NBS Circular No. 462 [3]. In these publications noise grade maps and prediction curves were given, indicating the noise level in terms of the minimum required signal strength to assure radio-telephone communication for 90 % of the time in the presence of atmospherics.

A more recent publication, NBS Circular No. 557 [4] presents the same noise grade maps as used in the previous publications. However, the prediction curves have been revised to show the expected median levels of radio noise during four-hour time blocks for each season instead of the required field strength for 90 % intelligibility. The method of interpreting the earlier predictions was not entirely clear and the present method of presenting those data has been used to remove the ambiguities so that further data can be compared with them more readily.

The compilation of more recent data indicates that, although the predictions presented in Circulars No. 462 and 557 have been found useful by many administrations, large discrepancies appear between measured values and the expected values from the predictions for some locations and times. For this reason, the preparation of entirely new predictions was undertaken.

These new predictions show primarily the expected values of a selected parameter of the atmospheric noise passed by a narrow-band filter. Values are given on a world-wide basis for all frequencies from 10 kc/s to about 30 Mc/s for all times of the day and night and all seasons of the year.

In preparing this report, slightly more emphasis was placed on data recorded during periods of high sunspot-activity than on data recorded during periods of low sunspot-activity when both were available. Also the expected effect of high sunspot-activity was to a small extent considered in determining the diurnal variations of the noise at locations where no data were available. Since we are now in a period of high sunspot-activity, this method should give the best estimates of the expected noise in the near future. While it is felt that the phase of the sunspot cycle will affect the

* This Report, which was adopted unanimously, is the Second Edition of Report No. 65. It is identical in substance with the First Edition (see pp. 324-359 of Volume I of Warsaw, 1956) but contains some minor amendments of a purely editorial nature (see minutes of the Third Plenary Meeting, Los Angeles, 1959, Volume V).

amount on received noise, it has not been possible to show satisfactory sunspot, correlation with the available noise data. Therefore, no further account, other than the above, has been taken of the phase of the sunspot cycle.

Wherever possible, the predictions are based on actual measurements. Unfortunately, even in recent years measurements have been made by a number of different methods and many are difficult to interpret. Also, measurements are often vitiated by the presence of man-made noise or by lack of sensitivity in the equipment.

2. The basic parameters.

The basic parameter, F_a [4], used to describe the noise is related to the noise power available from a short, vertical, earthed, loss-free antenna. If the antenna is short compared with the wavelength, the available power is independent of its length.

The noise power allows large, rapid fluctuations, but if it is averaged over several minutes, the average values are found to be nearly constant during a given hour; the variations of the average seldom exceed 2 or 3 db except during sunrise or sunset periods or during a local storm. The basic parameter used is, therefore, the median value of the average power during a period of one hour—called the hourly value. In using the noise measurements where the noise was sampled for only a few minutes each hour, it is assumed that the result represents the hourly value.

The hourly value, in terms of F_a , is expressed in decibels relative to the thermal noise power which would be available from the antenna if it were at a specified temperature, T . F_a may, therefore, be regarded as an effective antenna noise figure. The reference power level is kTB watts where:

k = Boltzmann's constant = 1.38×10^{-23} joules per degree Kelvin,

T = reference room temperature = 288°K ,

B = effective noise bandwidth in cycles per second.

In this report, the value of T has been chosen as 288°K so that with the value of k given above, $10 \log_{10} kT$ will equal $-204 \text{ db rel. to } 1 \text{ joule per c/s}$. If the noise figure measurements are made at significantly different temperatures, they can be adjusted to this value for convenience and uniformity.

Since the available noise power from all sources is assumed to be proportional to bandwidth, as is the reference power level, F_a is independent of bandwidth.

F_a in db is simply related to the r.m.s. field strength at the antenna by the following equation:

$$E_n = F_a - 65.5 + 20 \log_{10}$$

where

E_n = the r.m.s. field strength for a 1 kc/s bandwidth in db relative to $1 \mu\text{V/m}$,

f = the frequency in Mc/s.

It should be noted particularly that this is an effective field strength; that the composition of the incident waves may be complex, and cannot be deduced from measurements on a single vertical antenna. Therefore, E_n represents only the vertically polarized component.

3. The plotted parameters.

It is not practicable to quote the hourly values F_a and E_n for all times and places. The presentation of the data has been simplified by considering the four seasons and six four-hour periods of the day. The time period defined by a given four-hour period of the day and a season is a time block. Thus, there are, in the year, 24 time blocks each consisting of about 360 hours (four hours on each of about 90 days).

For the purpose of this report, the year has been divided into four seasons of three months each, as follows:

Months	Seasons	
	Northern Hemisphere	Southern Hemisphere
December, January, February	Winter	Summer
March, April, May	Spring	Autumn (Fall)
June, July, August	Summer	Winter
September, October, November	Autumn (Fall)	Spring

The plotted parameter is the median hourly value for each time block and the variations in this parameter show the diurnal and seasonal variations of the noise. In the present state of our knowledge, the variations of the hourly values within a time block must be treated as random, and their extent is indicated by the ratios of the upper and lower decile values to the medians. (See § 6.)

4. Factors involved in the predictions.

For convenience, the factors involved in preparation of the predictions are summarized below:

4.1 *Type of antenna.*

A vertical earthed monopole, short compared with the wavelength, is assumed.

4.2 *Basic parameter.*

The hourly median value of the available noise power expressed in terms of an effective noise figure, F_a , is used as the basic parameter. The effective field strength at the antenna, E_n , is also given.

4.3 *Plotted parameters.*

The plotted parameters used in these predictions are the median values of F_a and E_n , denoted by F_{am} and E_{nm} , for a time block. The time block is defined as the aggregate of all hours within a given four-hour period of the day and a given season.

4.4 *Time variations.*

As an indication of random variations of the hourly values within a time block, typical figures are given for the ratios of upper and lower decile values to the median.

4.5 *Location.*

Results of actual noise measurements are available for only a few places. The data used were obtained from references [4, 5, 6, 7, 8 and 9] of the bibliography. Additional data were obtained from the following reports:

COTTONY, H. V. Memorandum report on observations of atmospheric radio noise in arctic regions, *U.S. Department of Commerce, National Bureau of Standards, C.R.P.L.*, (Jan. 1948).

DINGER, H. E., GARNER, W. E., LEAVITT, G. E. Measurements of some low and very low frequency atmospheric noise in the Alaskan area, *N.R.L. Report No. 3958*.

NORTON, K. A., BATEMAN, R., ELLERT, C. A. Statements made at the Ship Power Hearing, *Federal Communications Commission, Report No. 30 539*, (November 14, 1938).

ALLEN, E. W., Jr. *Report of Committee No. 1, Part III, FCC Clear Channel Hearing, Docket 6741*, (February 15, 1946).

Data were also used from additional measurements made in the United States by the Central Radio Propagation Laboratory and in the United Kingdom by the Radio Research Station. Values for other parts of the world are deduced by interpolation, based on a knowledge of thunderstorm distribution [10] and of radio propagation characteristics.

4.6 Frequency.

The charts are drawn with contours of estimated noise level at 1 Mc/s. Values at other frequencies are obtained from those for 1 Mc/s by means of sets of curves.

4.7 Bandwidth.

Values of F_a are independent of bandwidth. Values of E_n are for 1 kc/s bandwidth and it may be assumed that the r.m.s. noise field is proportional to the square root of the bandwidth.

5. Description of the data.

Fig. 1 to 20 inclusive are charts showing the estimated median values of F_a in db at a frequency of 1 Mc/s for each of the 24 time blocks of the year. Corresponding values of E_{nm} in db relative to 1 $\mu\text{V/m}$ may be derived by subtracting 65.5 db from the plotted values. The difference between the time blocks 0000 to 0400 and 2000 to 2400 does not appear to be significant, as far as is known at present. Therefore, one chart is used for these two time blocks for each season.

Noise values at frequencies other than 1 Mc/s are derived by the use of Fig. 21 and 22 for F_{am} , of Fig. 23 and 24 for E_{nm} ; the 1 Mc/s noise value is obtained from a chart and the curves are used to extrapolate to the desired frequency. Fig. 21 or 23 are used for daylight at the receiving point and Fig. 22 or 24 for night-time. While the variation of noise with frequency is found to vary to some extent from place to place, these curves appear to represent the variations as well as is justified by the accuracy of the data available at present.

The differences between the law for daytime and night-time frequency curves result primarily from changes in propagation conditions, and these have been allowed for by using different sets of curves according to the predominance of daylight or darkness during a given time block. The sunrise (0400 to 0800) and sunset (1600 to 2000) times have varying percentages of daylight and darkness depending on latitude and season, and this complicates the presentation of the data. However, it has been decided that the existing data do not justify sub-division of these time blocks into dark and daylight hours and, therefore, the daylight curves are used for the whole time block in spring and summer and the night-time curves for autumn and winter. Further comments on the use of the curves for these periods, and on the particular difficulties involved at the equator are given in § 8.

A curve of galactic noise at frequencies above 1 Mc/s is shown [4]. There are small variations with time about this curve, but they are less than ± 2 db. Galactic noise is significant only at frequencies above the vertical-incidence critical frequency at any given time which is normally much higher than 1 Mc/s except in polar regions.

In many locations man-made noise will be a limiting factor in radio communication for at least part of the time. Although this type of noise must depend on local conditions, a curve of expected values at a quiet receiving location has been added. The values plotted are typical of the lowest values at sites chosen to insure a minimum amount of man-made noise and much lower values will seldom be found at sites which are not several kilometres from power lines and electrical machinery. Man-made noise may arise from any number of sources such as power lines, industrial machinery, ignition systems, etc. with widely varying characteristics. Propagation of man-made noise is principally by conduction over power lines or by ground wave and is thus relatively unaffected by diurnal or seasonal changes in the ionosphere. However, there is experimental evidence that man-made noise may also be received from distant sources by ionospheric propagation; for example, values of man-made noise of a few decibels above kTB at 2 Mc/s have been attributed to a large city at a distance of 65 kilometres (40 miles) when the receiving site was exceptionally free from local man-made sources and very few atmospherics and radio signals were

being received [11]. The only trend considered in this Report is the variation with frequency; the level decreases with increasing frequency, owing partly to the characteristics of the radiated spectrum and partly to propagational factors.

It will be observed that values of noise at 1 Mc/s are indicated which are below the expected levels of man-made and galactic noise. These values should be used with caution, as they represent only rough estimates of what atmospheric noise would be recorded if other types were not present. They are useful mainly as reference levels for low-noise locations, a 1 Mc/s noise value being assigned by plotting data at other frequencies on the noise curve.

6. Noise level variations within a time block.

The hourly values for a given time block vary from hour to hour and from day to day. The extent of these variations is shown in Fig. 25, on which are plotted the ratios in db of the upper decile to the median values, D_u , and of the median to the lower decile values, D_l . These ratios depend on a number of parameters, but the frequency has been found to be the most significant. D_u has its highest values at sunrise and sunset owing to the change from day-time to night-time propagation conditions and also during the afternoons owing to the occurrence of local storms.

Fig. 26 is an example of the distribution of the hourly values within a time block. It may be noted that the curve, typical of a large number of curves of this type, can be represented on normal probability paper with reasonable accuracy by two straight lines, one of which passes through the upper decile and median and the other passes through the median and lower decile. Thus, a knowledge of these three values which can be obtained from the predictions will enable a good estimate to be made of any percentile value between 1% and 99%.

At those locations where man-made noise from local sources has been studied, it has been found that the variations are similar in extent to those of atmospheric noise.

7. The fine structure of atmospheric noise.

The variations of the noise envelope in periods of the order of milliseconds depends on the bandwidth of the receiver. The noise is partly impulsive, and the wider the bandwidth the higher and narrower are the peaks. The following remarks, therefore, apply to bandwidths normally used for radio services—say 300 c/s at a frequency of 10 kc/s increasing to several kc/s for frequencies of 300 kc/s and above.

At the lowest frequencies the noise consists largely of impulses separated by periods of relatively low noise. The larger peaks have a shape characteristic of the pass-band of the receiver, but the smaller peaks, which are more numerous, run into one another and constitute more continuous noise. The large peaks, though relatively few in number, contribute substantially to the noise power, which could, therefore, be much reduced by amplitude limitation in the receiver. Such amplitude limitation will often take place in operational types or receivers in current use.

The structure of atmospheric noise at medium (MF) and high frequencies (HF) is more complex. In temperate latitudes, noise at 10 Mc/s consists of bursts, of the order of 10 to 100 ms long, with relatively quiet periods in between. The noise during a burst closely resembles fluctuation noise. In the periods between bursts the noise may be mainly of galactic origin, around mid-day, but at other times the minimum atmospheric noise level is above that of galactic noise.

8. Use of the data.

The data may be used in the form of either the r.m.s. noise field strength E_n , or the noise figure, F_n . In Recommendation No. 161 [12], the required signal-to-noise ratios for various services under steady conditions are given, the noise being expressed as the r.m.s. value in a 6 kc/s

bandwidth. The noise values for a 1 kc/s bandwidth given in this Report should be increased by 8 db to give the noise in a 6 kc/s bandwidth.

Since the signal-to-noise ratios in Recommendation No. 161 are for steady conditions, allowance must be made in practical problems for the random temporal variations of noise. Intensity fluctuation factors are given in Recommendation No. 164 where the upper decile intensity of noise is assumed to be 10 db above the median. From Fig. 25, it is seen that the allowance should be a function of frequency and that it should be greater than 10 db in the MF (hectometric) band but less than 10 db in the HF (decametric) band.

Considering shorter-term variations, reference has already been made to the variations over an hour of the noise averaged over a period of a few minutes (§ 2). These variations, are normally of only two or three decibels and are small compared with the allowances for fading of the signals (see Report No. 159). It is also found that fluctuations of noise averaged over periods of the order of ten seconds are small compared with fluctuations in signals, if these follow the Rayleigh distribution.

The difficulties in presenting the data for the sunrise and sunset periods (0400 to 0800 and 1600 to 2000) have already been mentioned. These are periods when large changes in noise level occur at some frequencies and the median value may be expected to depend rather critically on whether the receiving point is in daylight for more or less than half the period. In practical problems it will usually be necessary to reconstruct the diurnal curve of noise level and if this is done, having regard to both the median levels derived from the curves and the times of occurrence of sunrise and sunset, the final values should not be much in error. The equator, which has no seasons in the sense in which they are defined here, presents a special problem. To obtain uniformity in interpretation it is suggested that the average of the two values derived from the daylight and the night-time curves be used for locations on the equator. In future revision of the data, it may be possible to deal with this problem in a more elegant manner, but the necessary data do not at present exist.

If a more complete analysis of a receiving installation is required, for example to determine whether or not reception is limited by external noise or by noise sources within the receiving system, the method described in references [4 and 13] in the bibliography may be used as follows:

Fig. 27 is a block diagram in which the various elements that contribute to the resultant noise level are shown. Block *A* represents a loss-free antenna receiving external noise with an effective noise figure F_a . The losses in the antenna and associated circuit are represented in block *C*, whose noise figure is F_c . Similarly, the transmission line loss will determine a noise figure F_t , for the transmission line. The receiver noise figure is designated by F_r . Using Friis' [14] method of combining the noise figures (expressed as power ratios) of several networks in cascade, the effective noise figure (also expressed as a power ratio) at the input of the antenna is given by:

$$F = F_a - 1 + F_c F_t F_r$$

The minimum signal power available from the aerial that is required to provide satisfactory reception is:

$$P = F + R - 204 + 10 \log_{10} B$$

where

- P = available signal power (db relative to 1 watt),
- F = overall effective noise figure (db),
- R = required signal-to-noise ratio (db),
- B = bandwidth in c/s.

For example, using values of R given in Recommendation No. 161 where B is taken as 6 kc/s, then

$$P = F + R - 166$$

In making a system evaluation as described above, the value of F_a that is used may be the median, upper decile, or some other percentile, depending upon the protection required.

BIBLIOGRAPHY

1. I.R.P.L. Radio Propagation Handbook. *U.S. Department of Commerce*, National Bureau of Standards, (November 1943).
2. Minimum required field intensities for intelligible reception of radio telephony in presence of atmospherics or receiving set noise. *Radio Propagation Unit Technical Report, No. 5* (First Edition), Holabird Signal Depot, Baltimore, Maryland (December 1945).
3. Ionospheric radio propagation. *U.S. Department of Commerce*, National Bureau of Standards, Circular No. 462, 1948 (Government Printing Office, Washington, D.C.).
4. CRICHLAW, W. Q., SMITH, D. F., NORTON, R. N. and CORLISS, W. R. World-wide radio noise levels expected in the frequency band from 10 kilocycles to 100 Megacycles. *U.S. Department of Commerce, National Bureau of Standards, Circular 557* (August, 1955) (Government Printing Office, Washington, D.C.).
5. HORNER, F. Measurements of atmospheric noise at high frequencies during the years 1945 to 1951. *Radio Research Board, Special Report No. 26*, H.M. Stationary Office, London 1953, Code No. 47-29-26.
6. HOGG, D. The measurement of atmospheric radio noise in South Africa in the low-frequency band. *The Transactions of the South African Institute of Electrical Engineers*, 41, 200-225 (July 1950).
7. YABSLEY, D. E. Atmospheric noise levels at radio frequencies near Darwin, Australia. *Aust. Journ. Sci., Research, Series A*, 3, 409-416 (1950).
8. SULLIVAN, A. W., VAN VALKENBURG, H. M. and BARNEY, J. M. Low-frequency atmospheric radio noise in Florida. *Trans. Am. Geophysical Union*, Vol. 33, No. 3 (October 1952).
9. GERSON, N. C. Noise levels in the American sub-arctic. *Proc. I.R.E.*, 38, 905-916 (1950).
10. World distribution of thunderstorm days. *World Meteorological Organization Reports*, WMO/OMM No. 21, T.P. 6, Part I, 1953 and WMO/OMM, No. 21, T.P. 21, Part II (WMO Secretariat, Geneva) (1956).
11. PAWSEY, J. L., MCCREADY, L. L. and GARDNER, F. F. Ionospheric thermal radiation at radio frequencies. *Journ. Atmos. and Terr. Physics*, 1, 216-277 (1951).
12. Recommendation No. 161 of the C.C.I.R. (See page 119 of Volume I of Los Angeles).
13. NORTON, K. A. Transmission loss in radio propagation. *Proc. I.R.E.*, Vol. 41, 5, 146-152 (January 1953).
14. FRIIS, H. T. Noise figure of radio receivers. *Proc. I.R.E.*, Vol. 32, 8, 419-422 (July 1944).

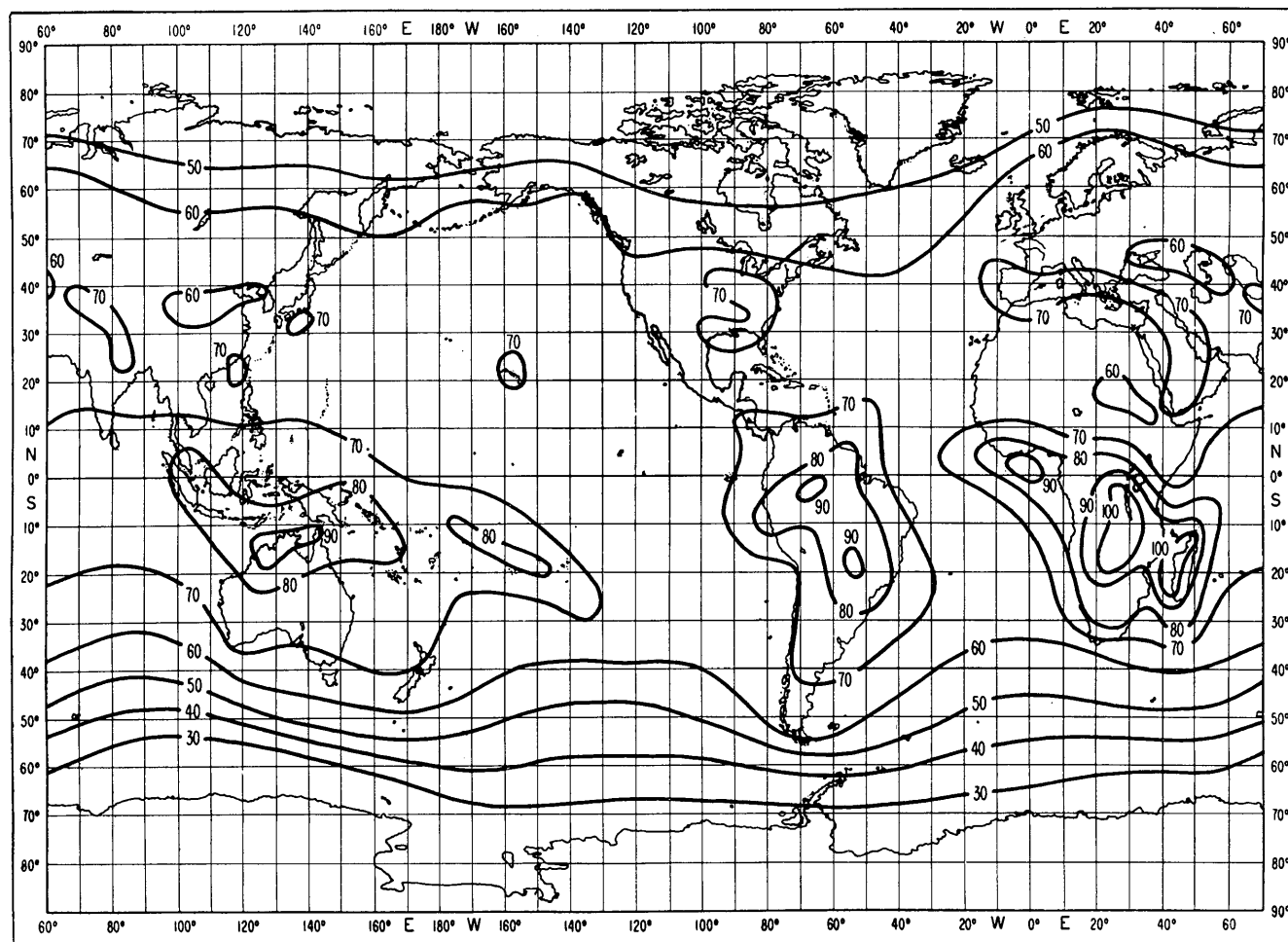


FIGURE 1

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0000—0400 hrs
and from 2000—2400 hrs, for December, January and February*

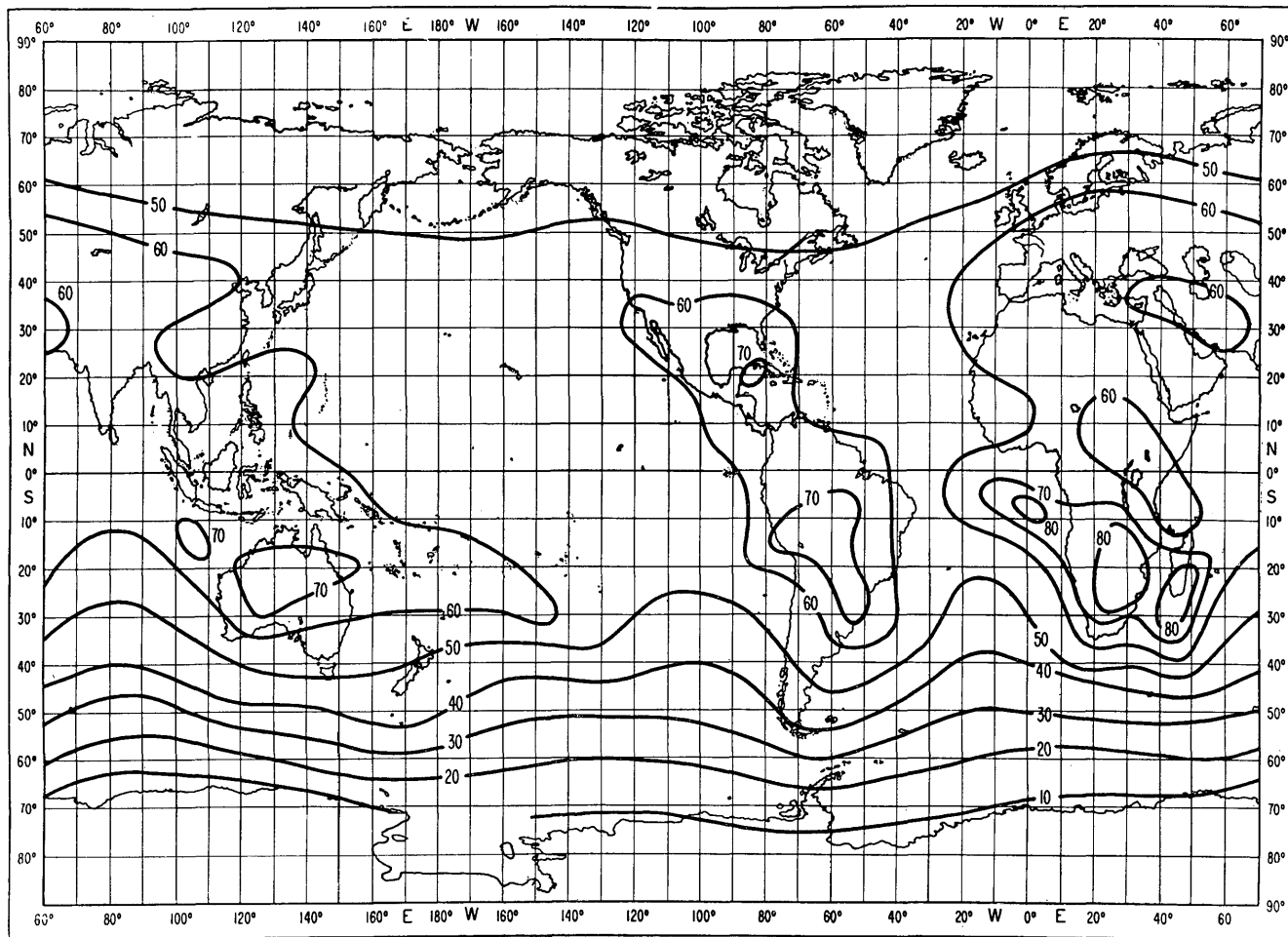


FIGURE 2

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0400—0800 hrs,
for December, January and February*



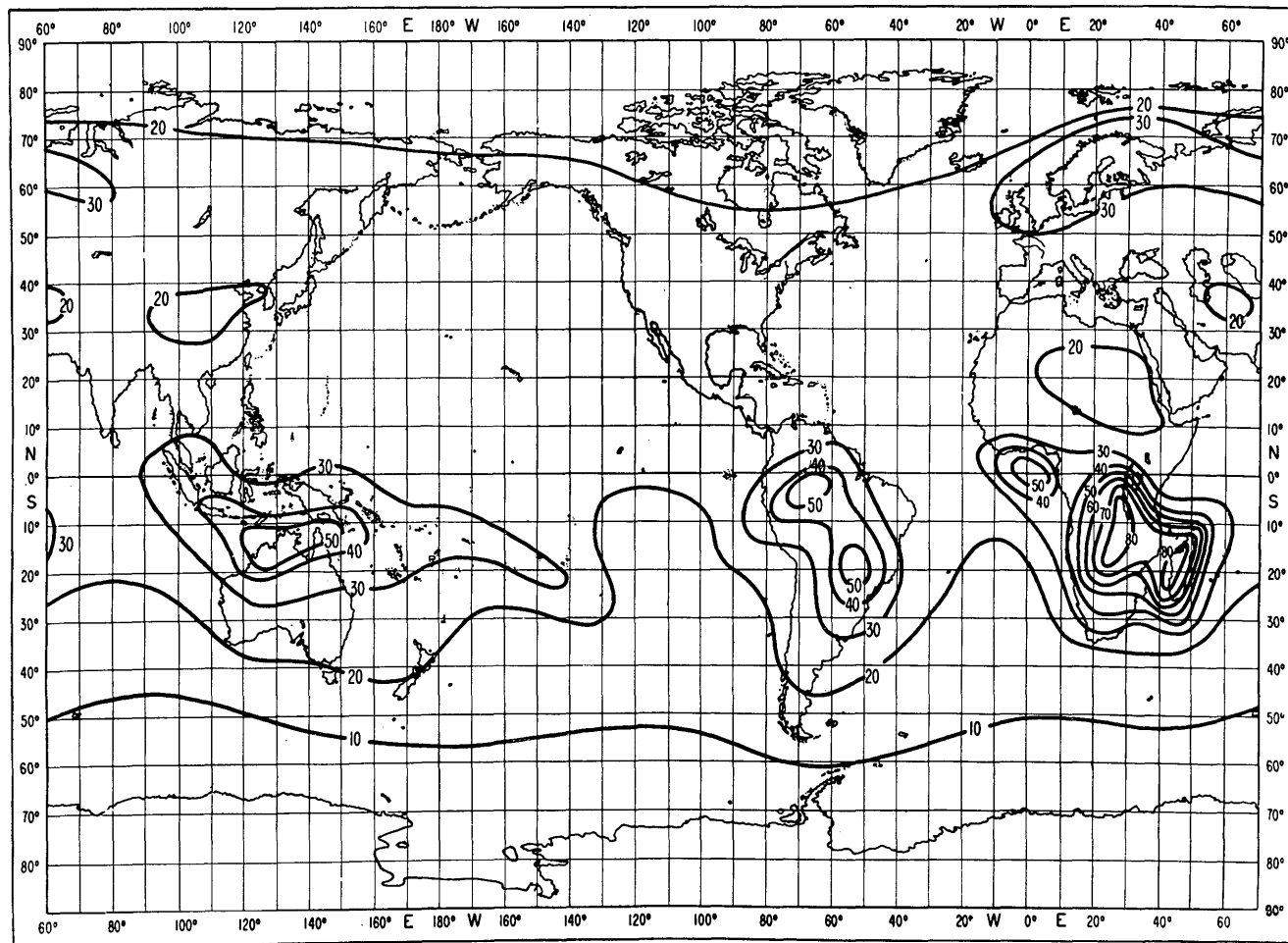


FIGURE 3

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0800—1200 hrs,
for December, January and February*

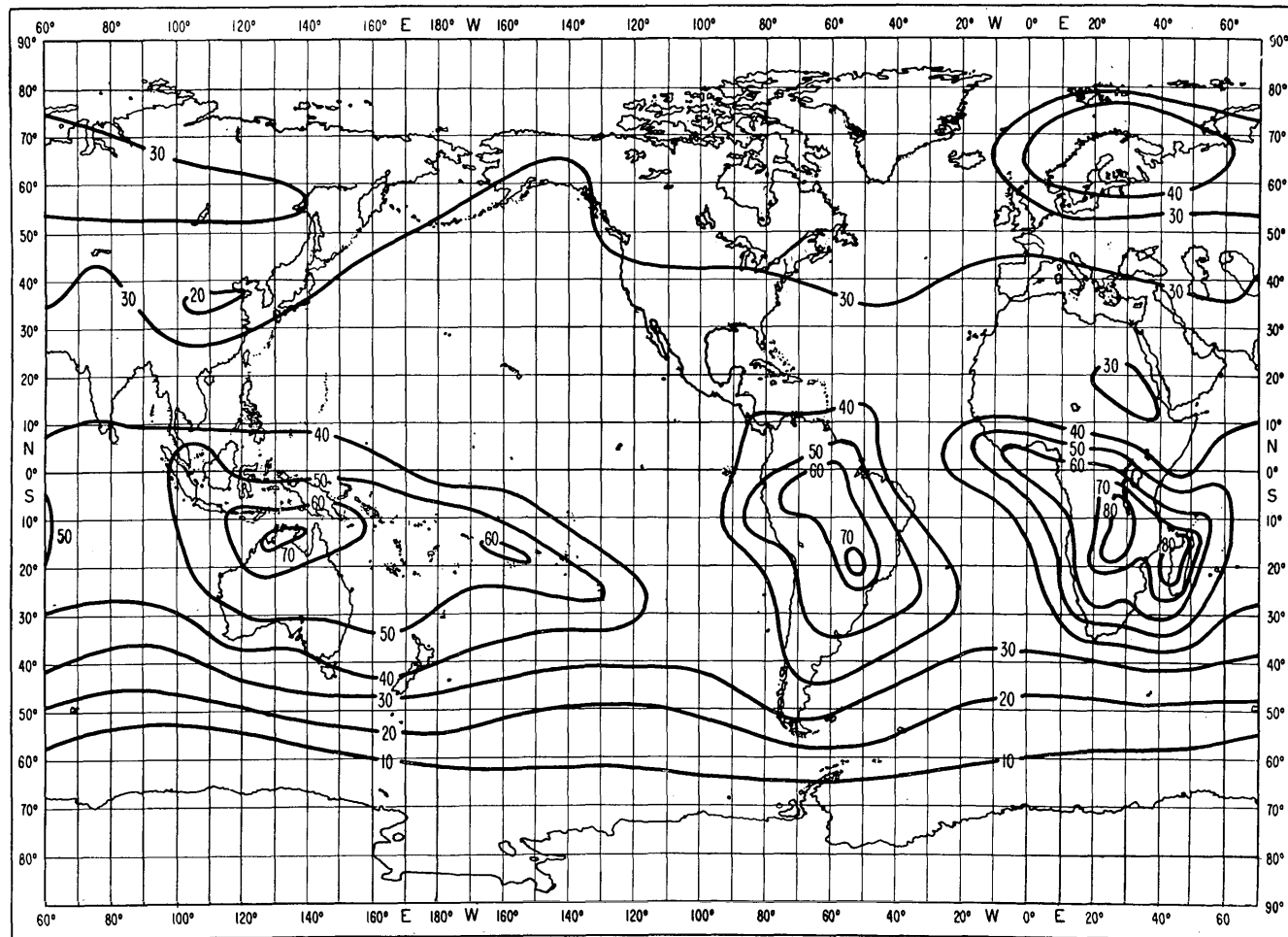


FIGURE 4

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1200—1600 hrs,
for December, January and February*

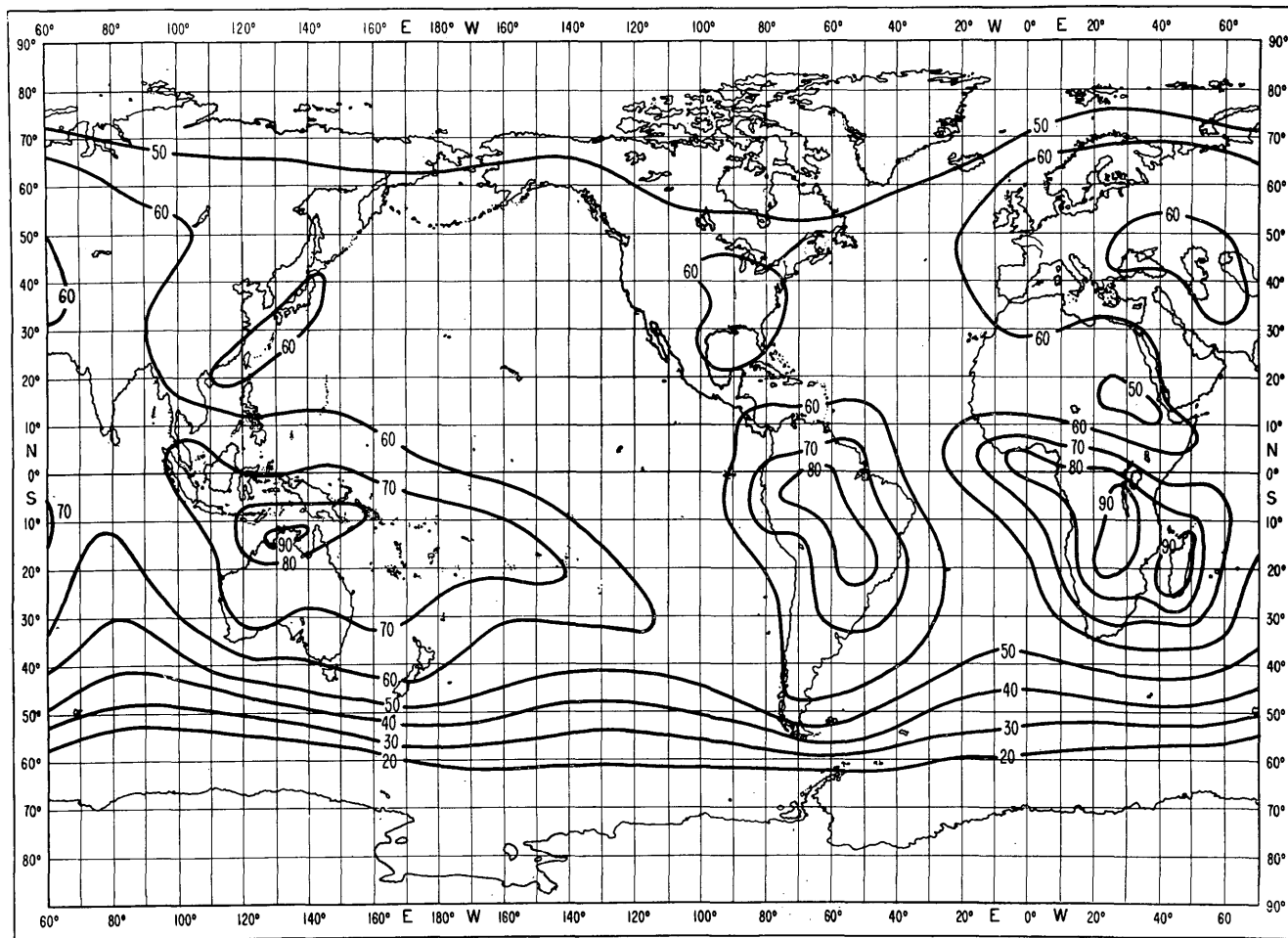


FIGURE 5

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1600—2000 hrs,
for December, January and February*

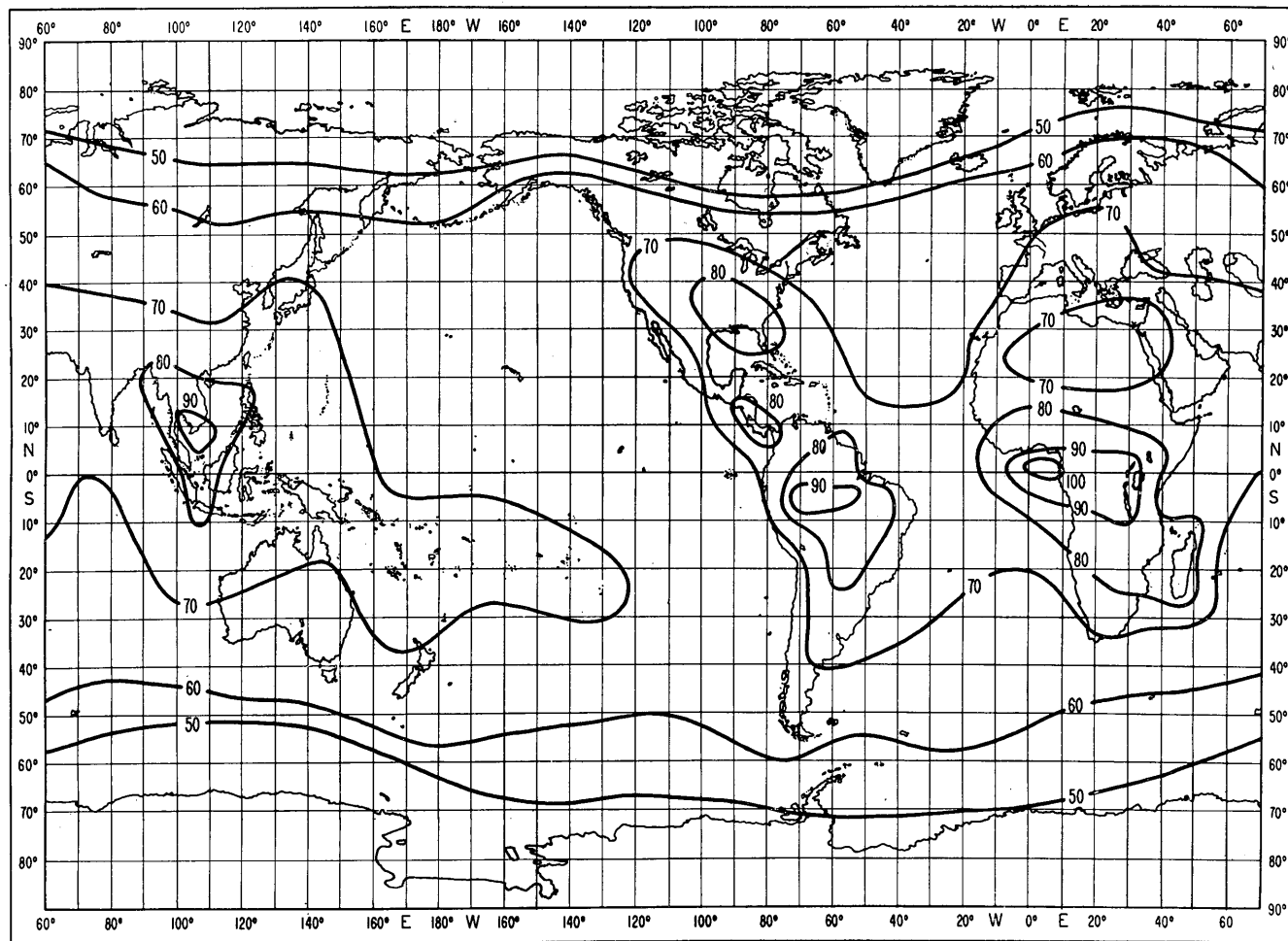


FIGURE 6

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0000—0400 hrs,
and from 2000—2400 hrs, for March, April and May*

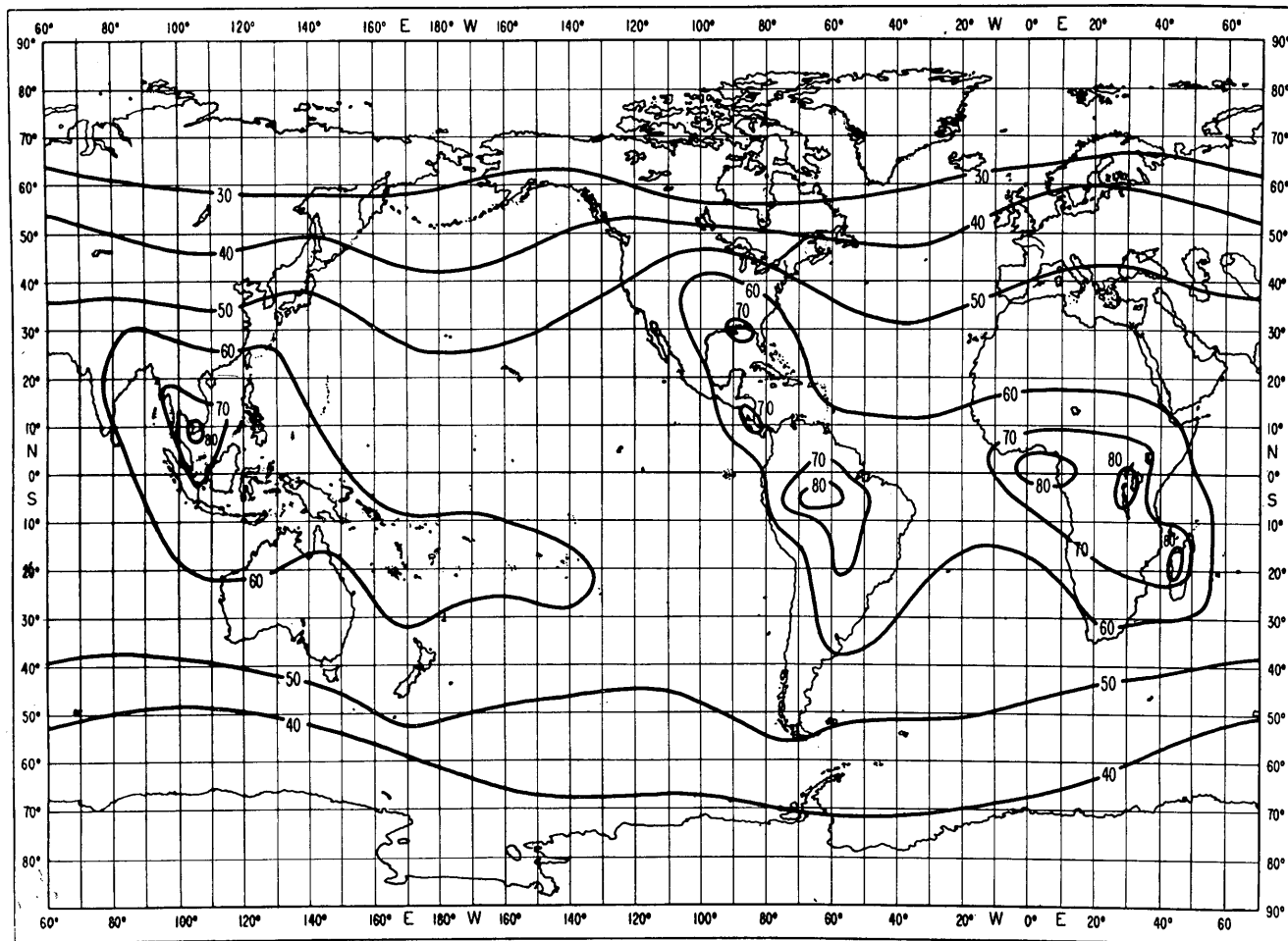


FIGURE 7

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0400—0800 hrs,
for March, April and May*

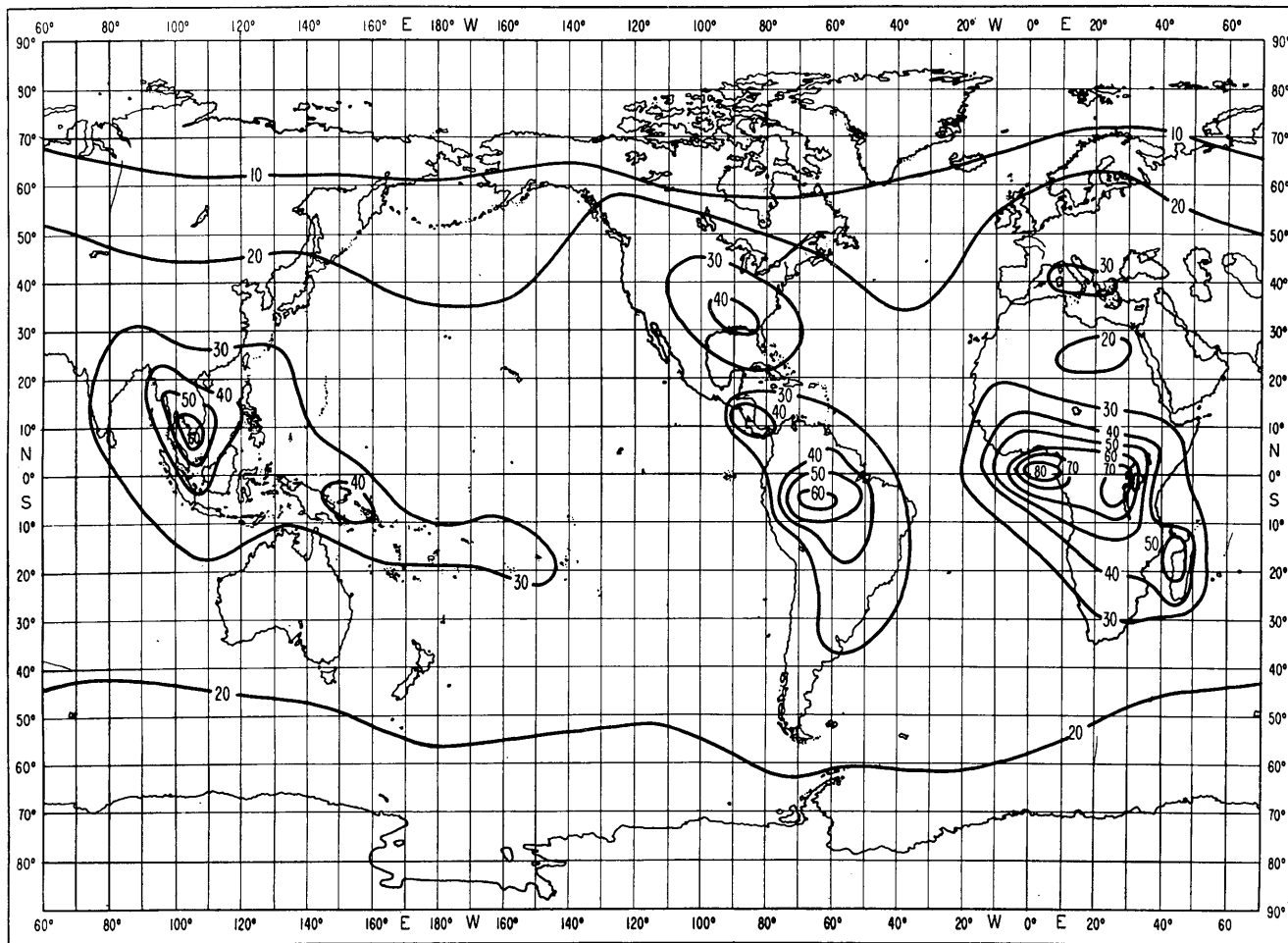


FIGURE 8

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0800—1200 hrs,
for March, April and May*



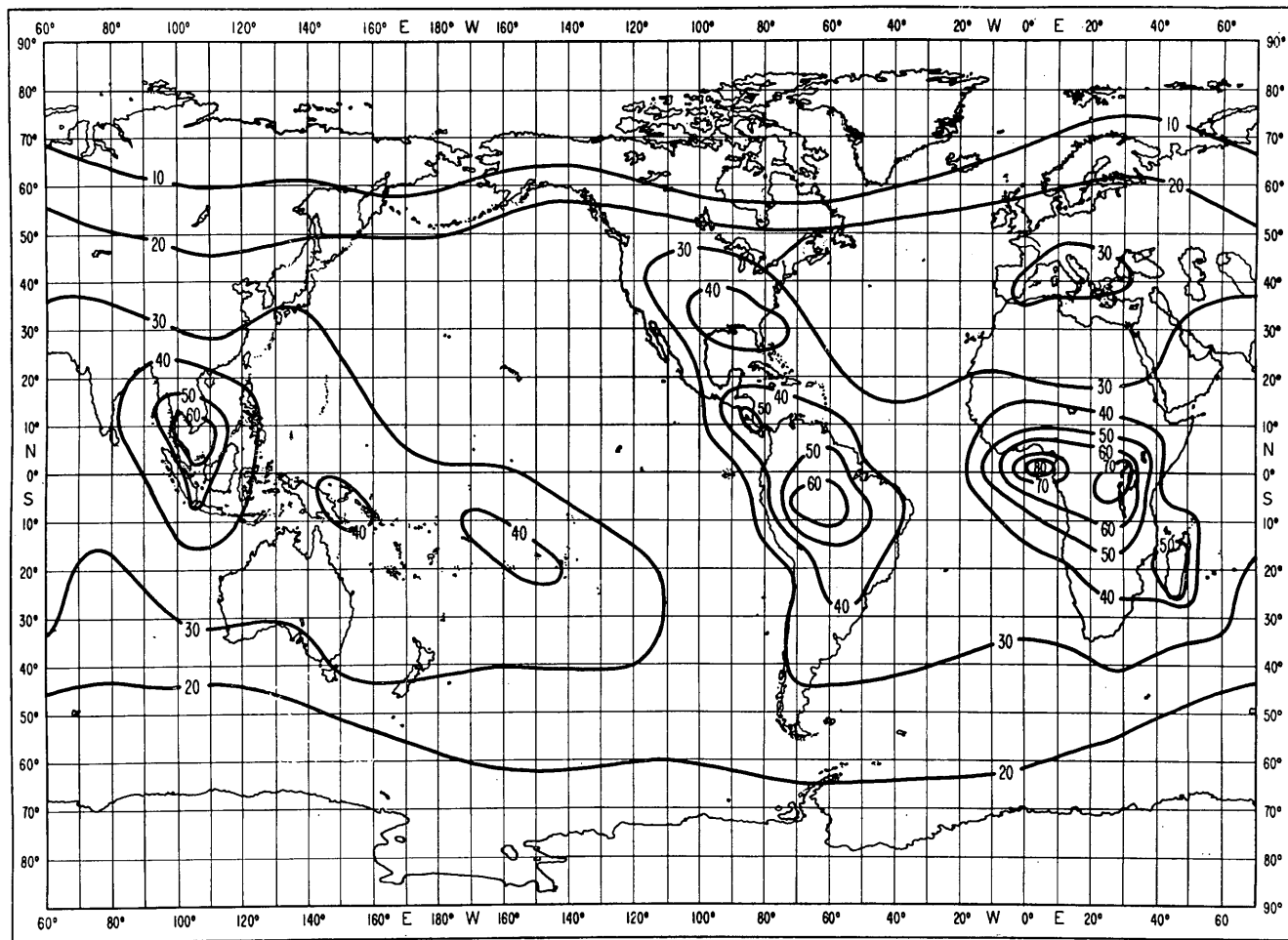


FIGURE 9
*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1200—1600 hrs,
 for March, April and May*

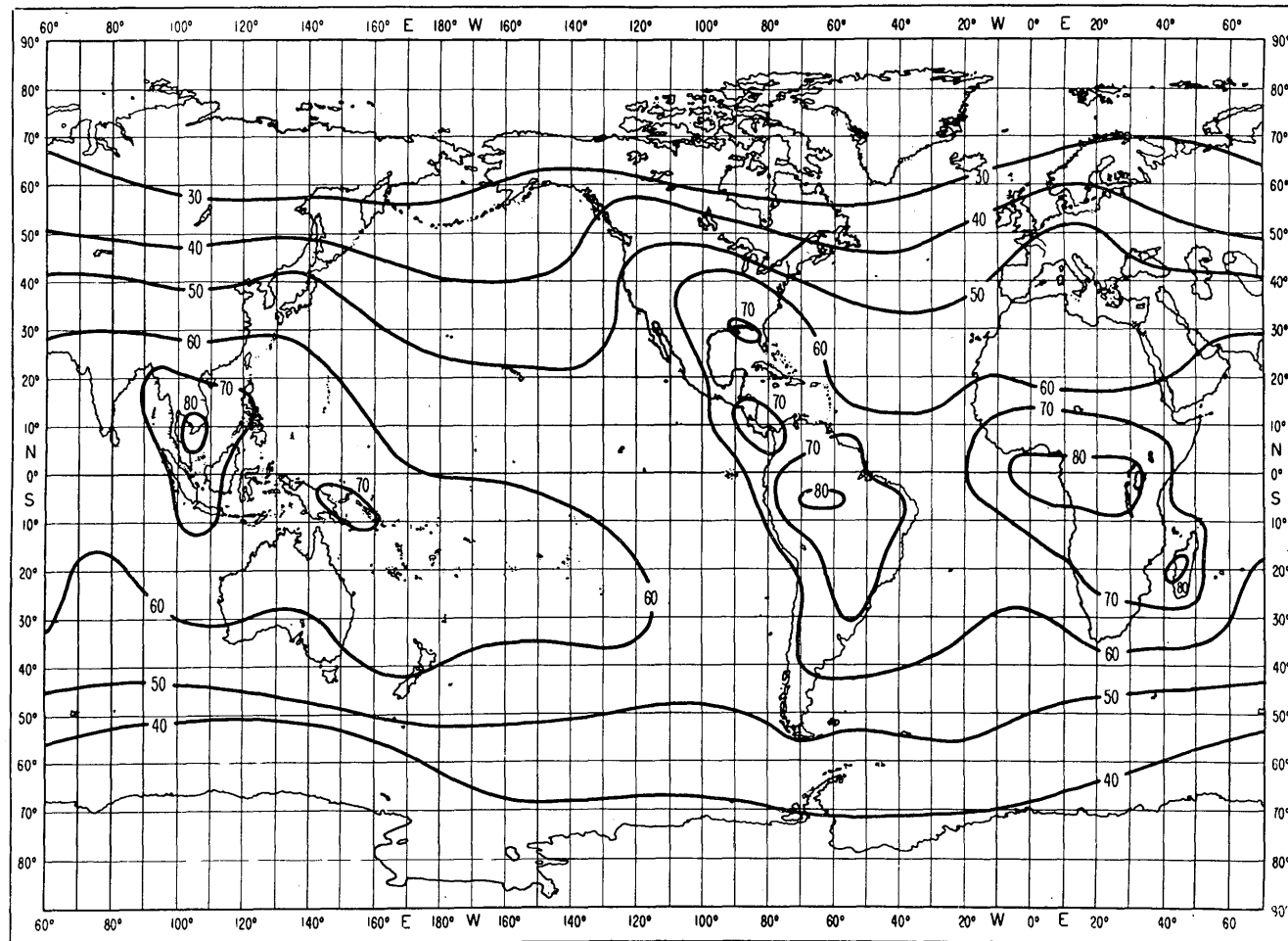


FIGURE 10
*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1600—2000 hrs,
 for March, April and May*



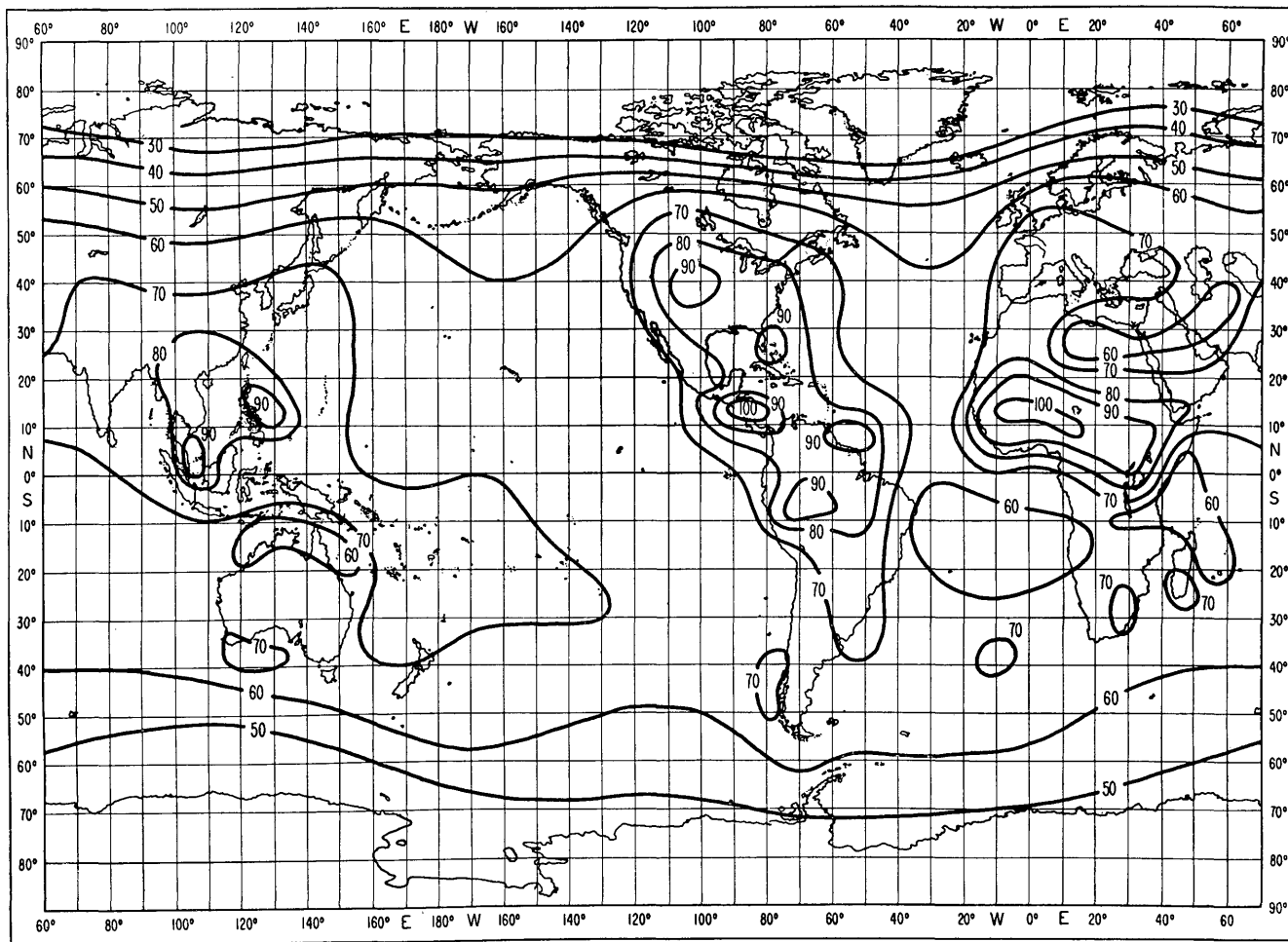


FIGURE 11

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0000—0400 hrs,
and from 2000—2400 hrs, for June, July and August*

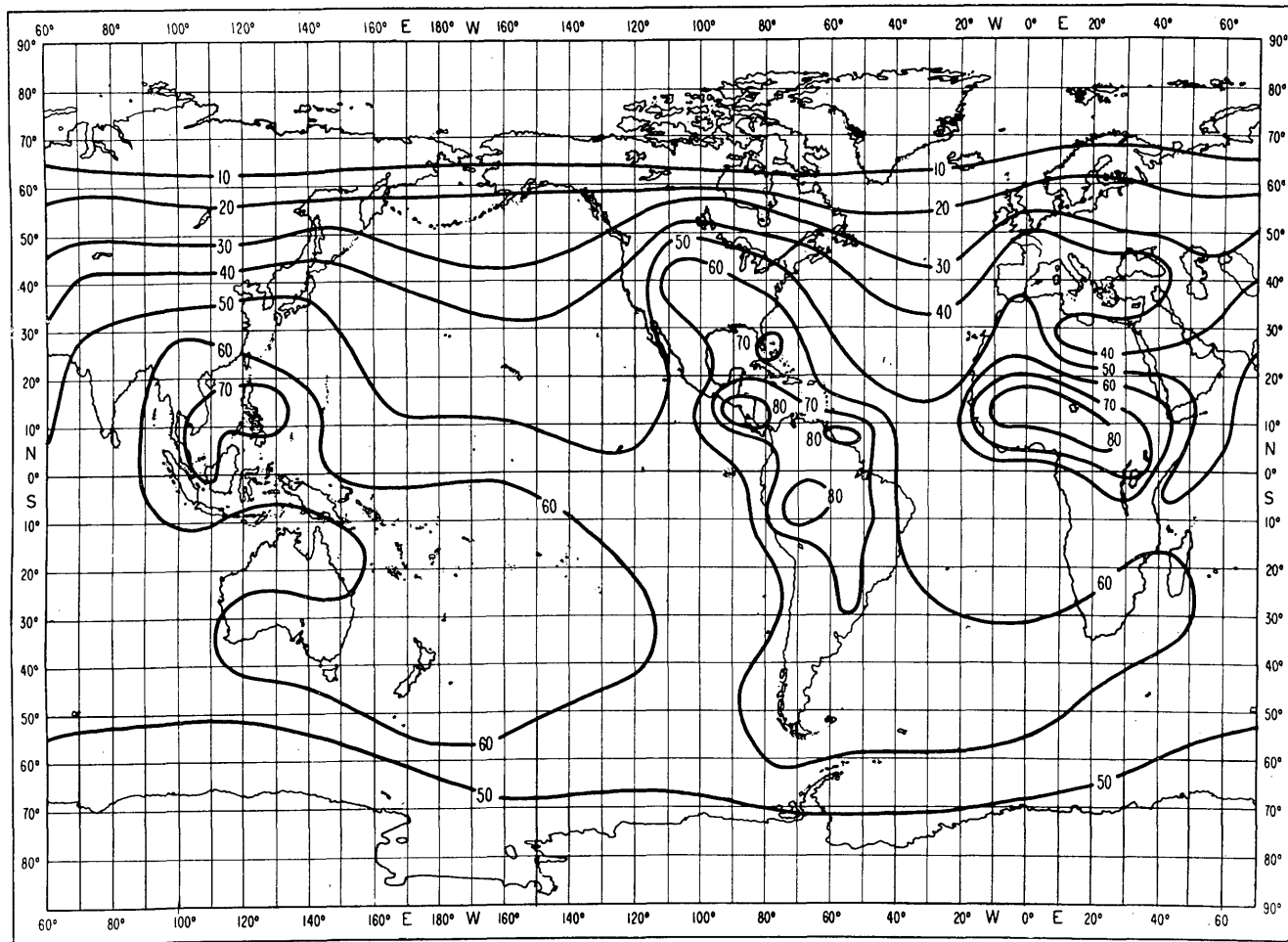


FIGURE 12

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0400—0800 hrs,
for June, July and August*



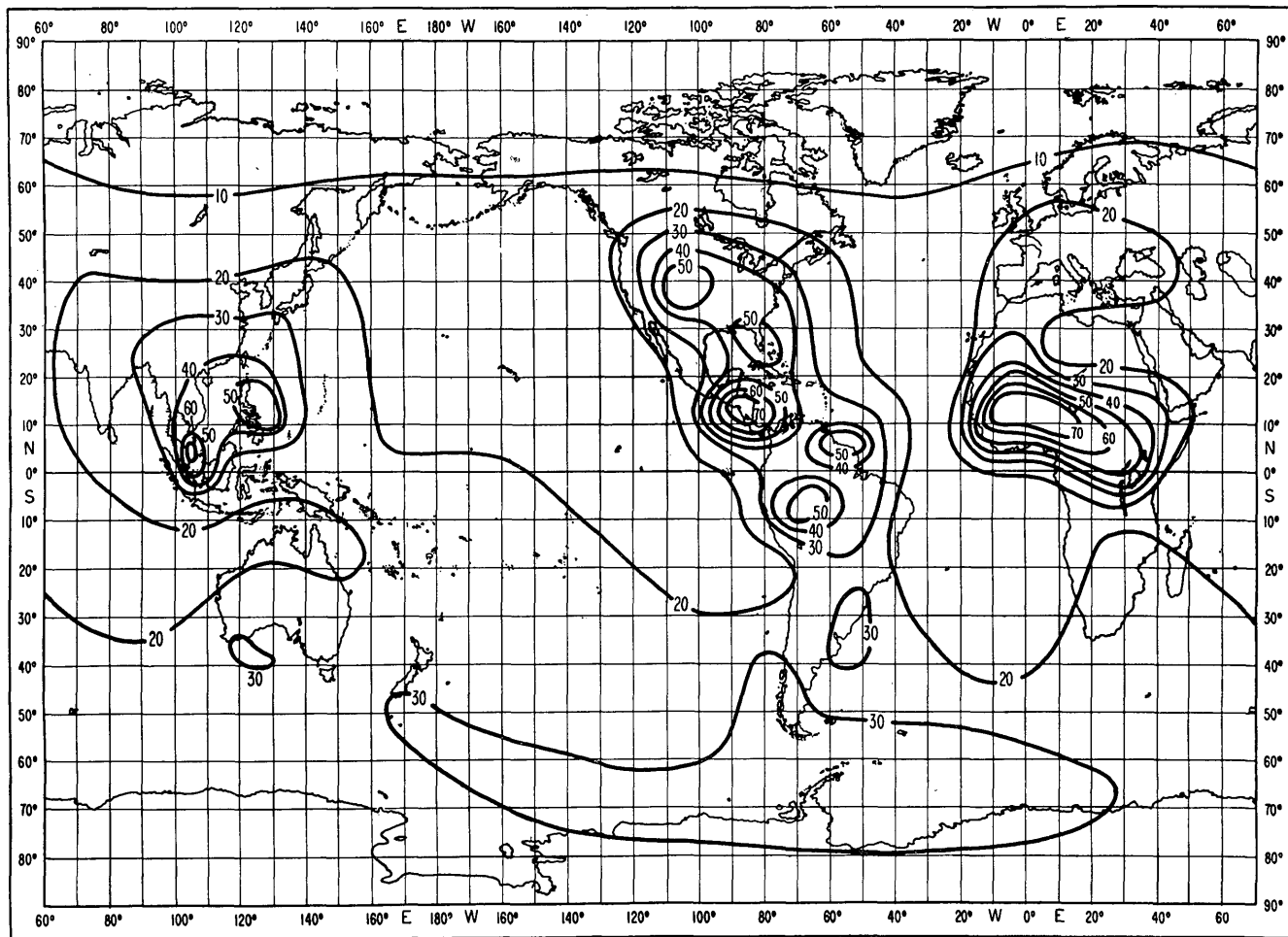


FIGURE 13

*Expected values of radio noise F_a (db rel. to kTB) 'at 1 Mc/s, from 0800—1200 hrs,
for June, July and August*

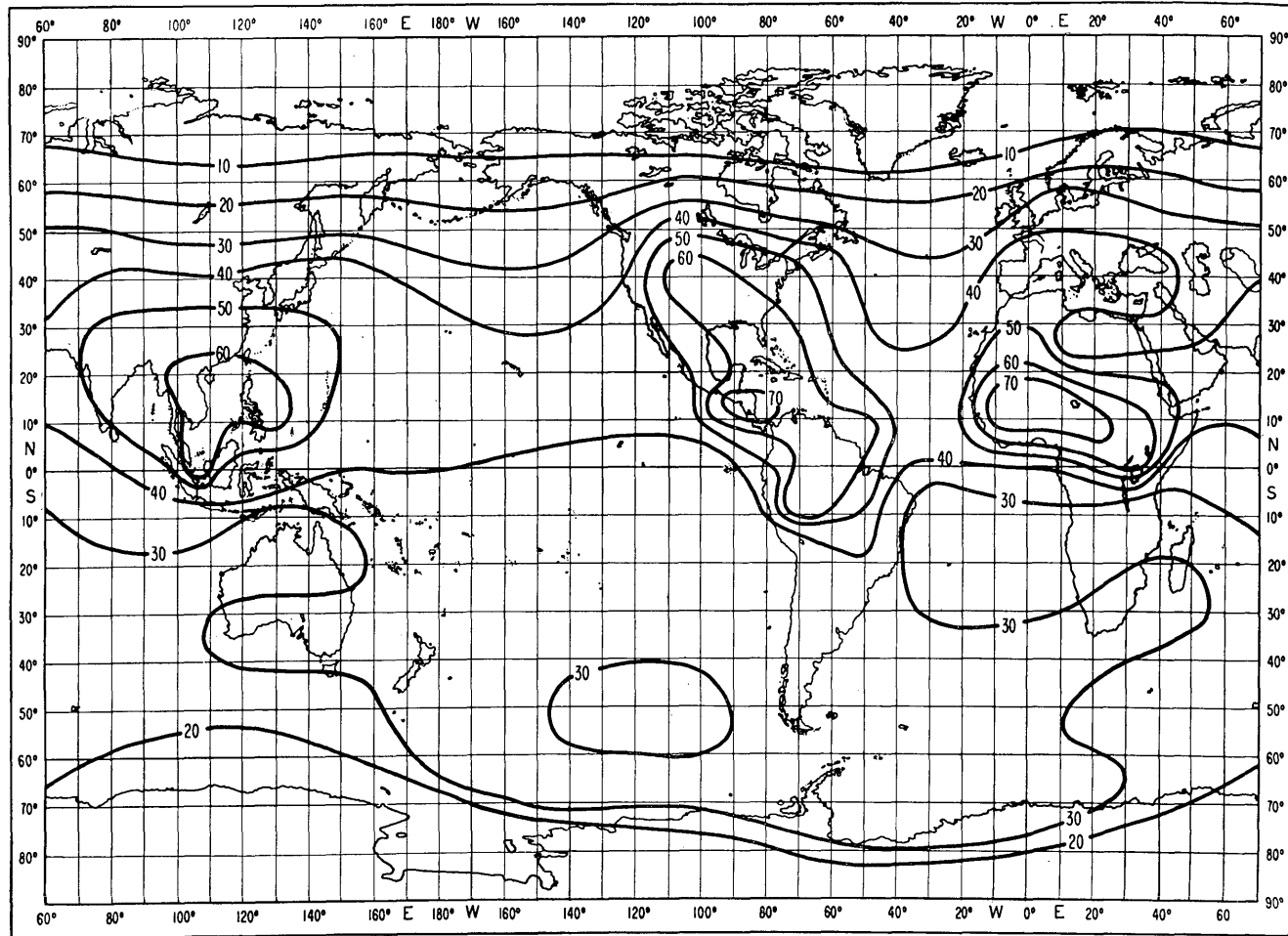


FIGURE 14

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1200—1600 hrs,
for June, July and August*



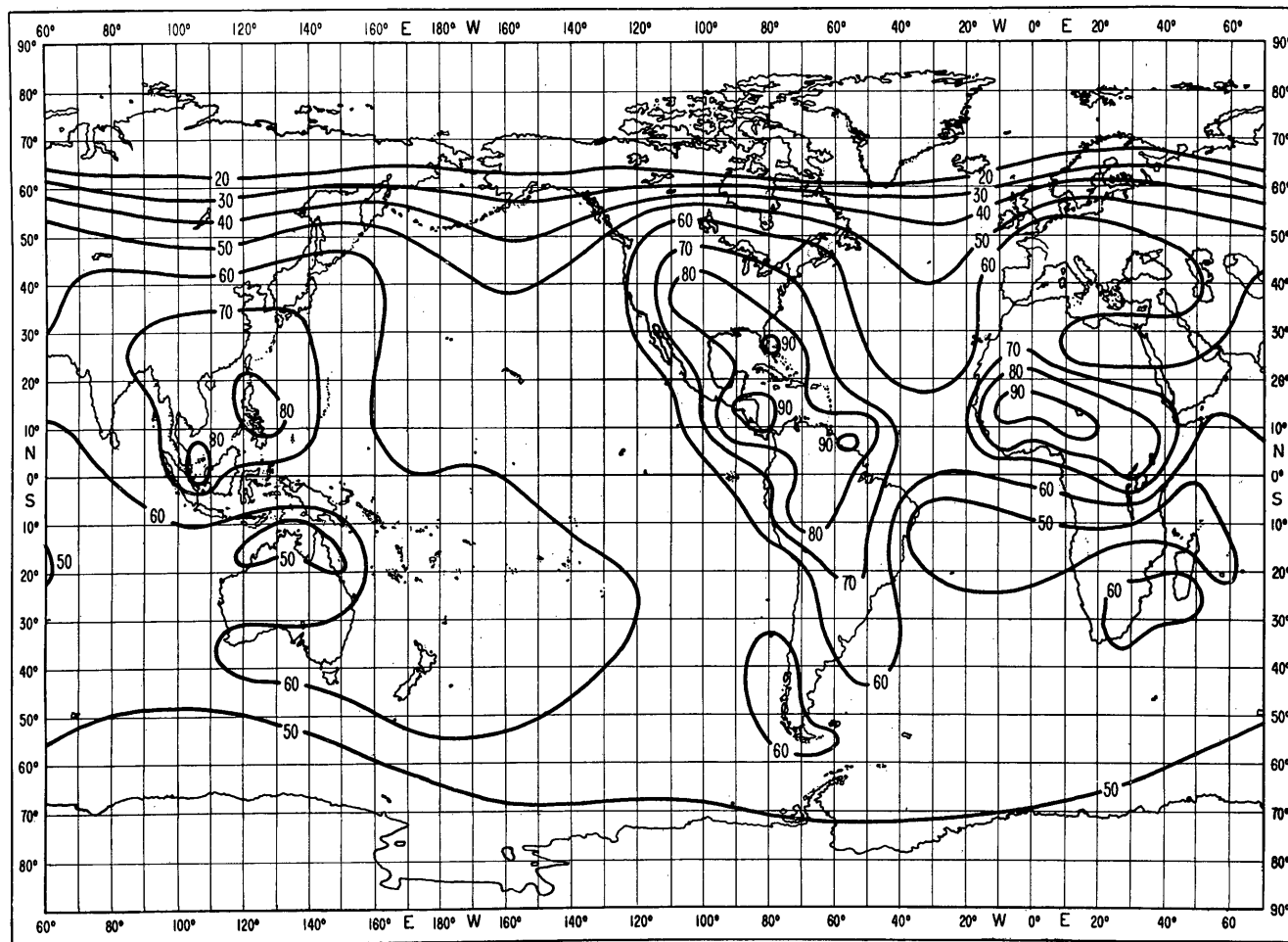


FIGURE 15

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1600—2000 hrs,
for June, July and August*

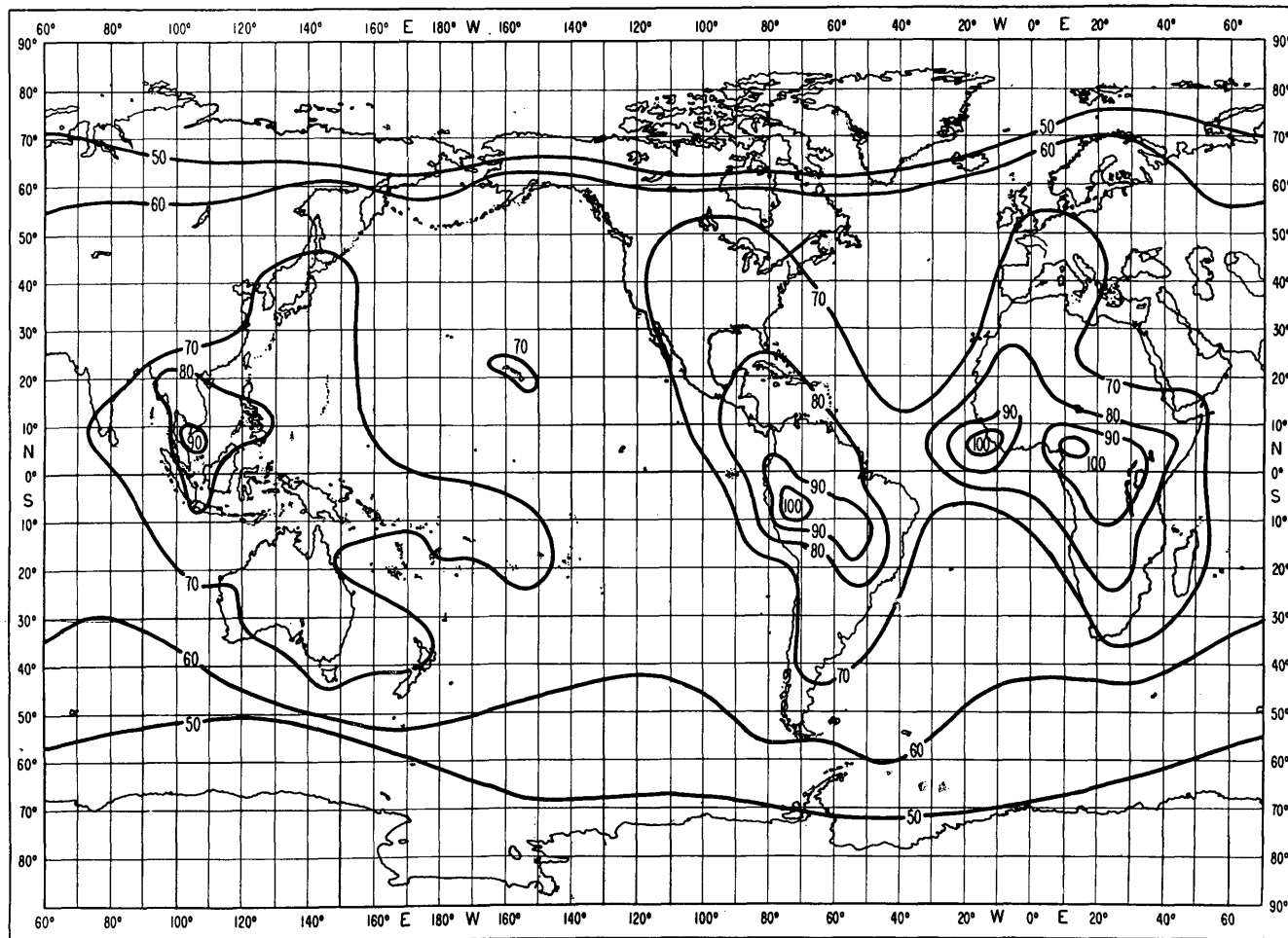


FIGURE 16

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0000—0400 hrs,
and from 2000—2400 hrs, for September, October and November*

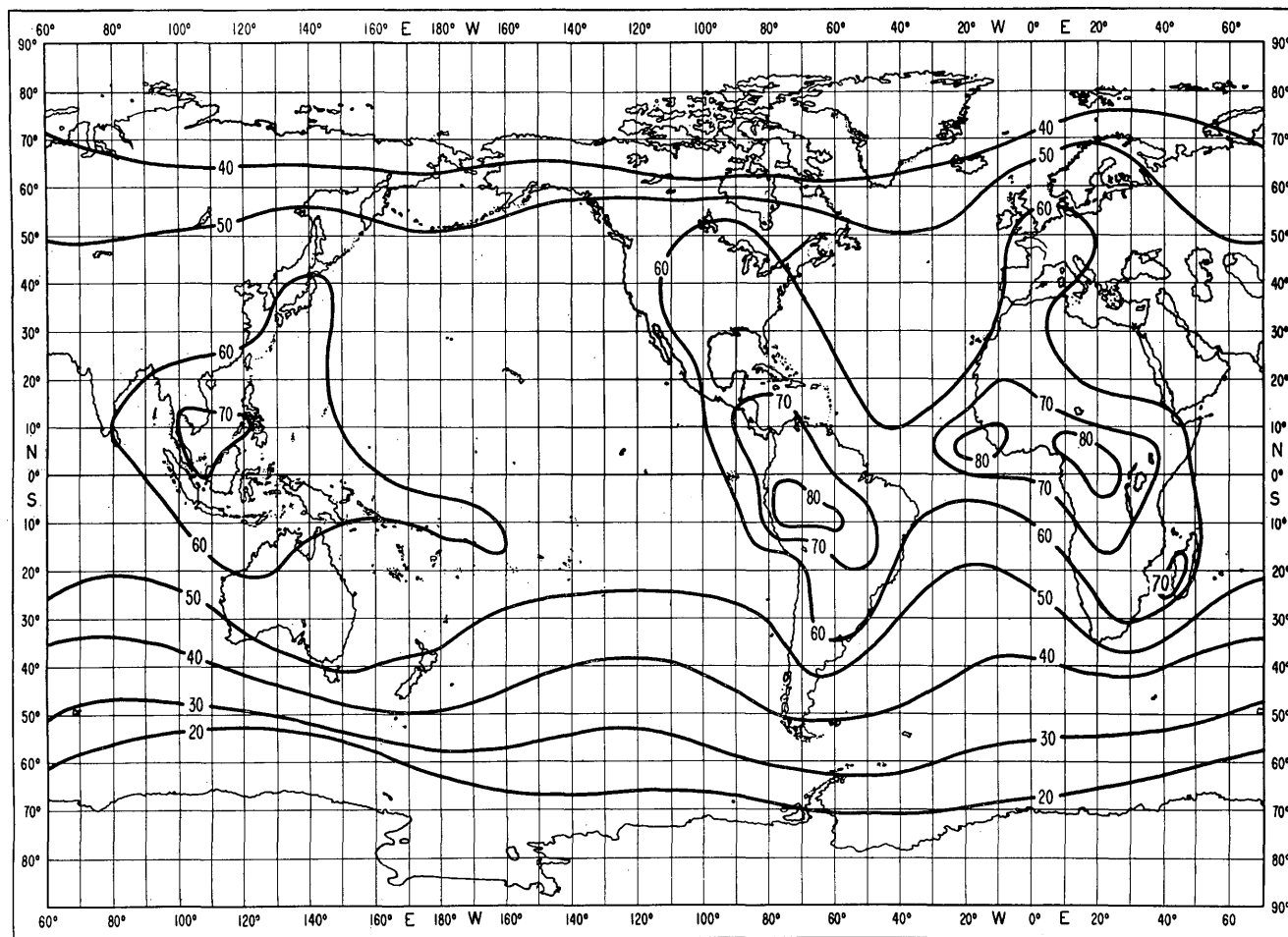


FIGURE 17

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0400—0800 hrs,
for September, October and November*

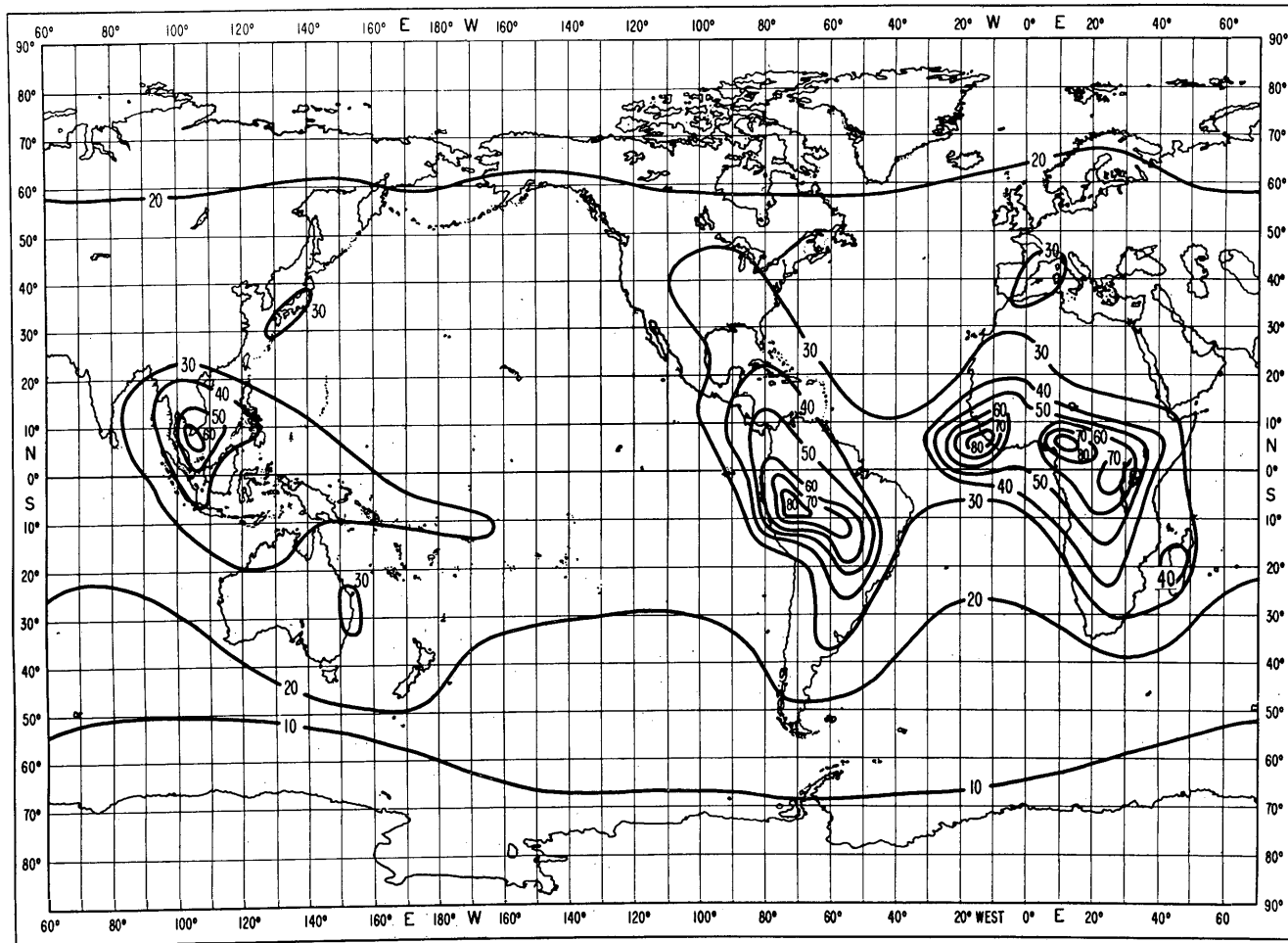


FIGURE 18

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 0800—1200 hrs,
for September, October and November*



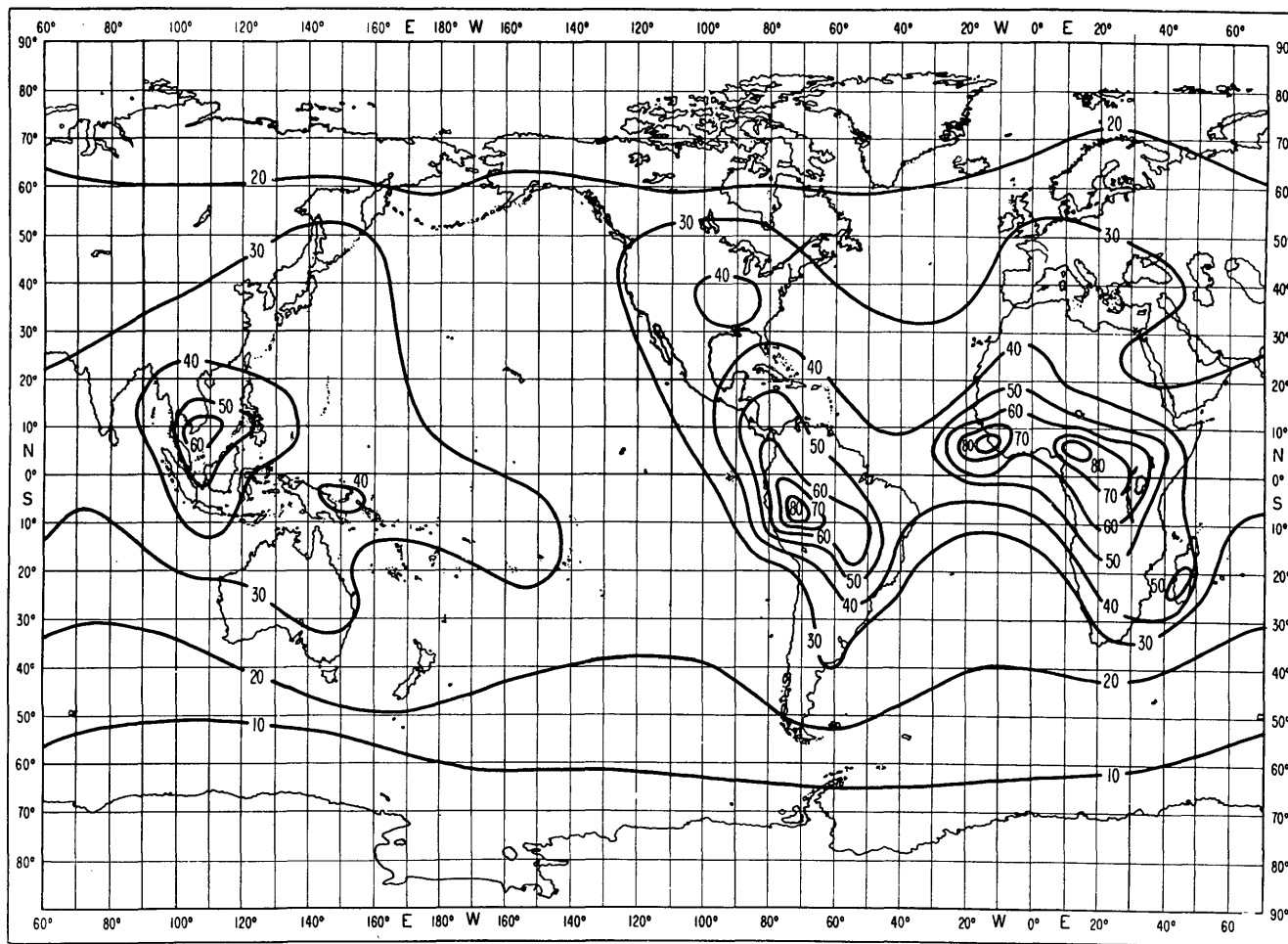


FIGURE 19

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1200–1600 hrs,
for September, October and November*

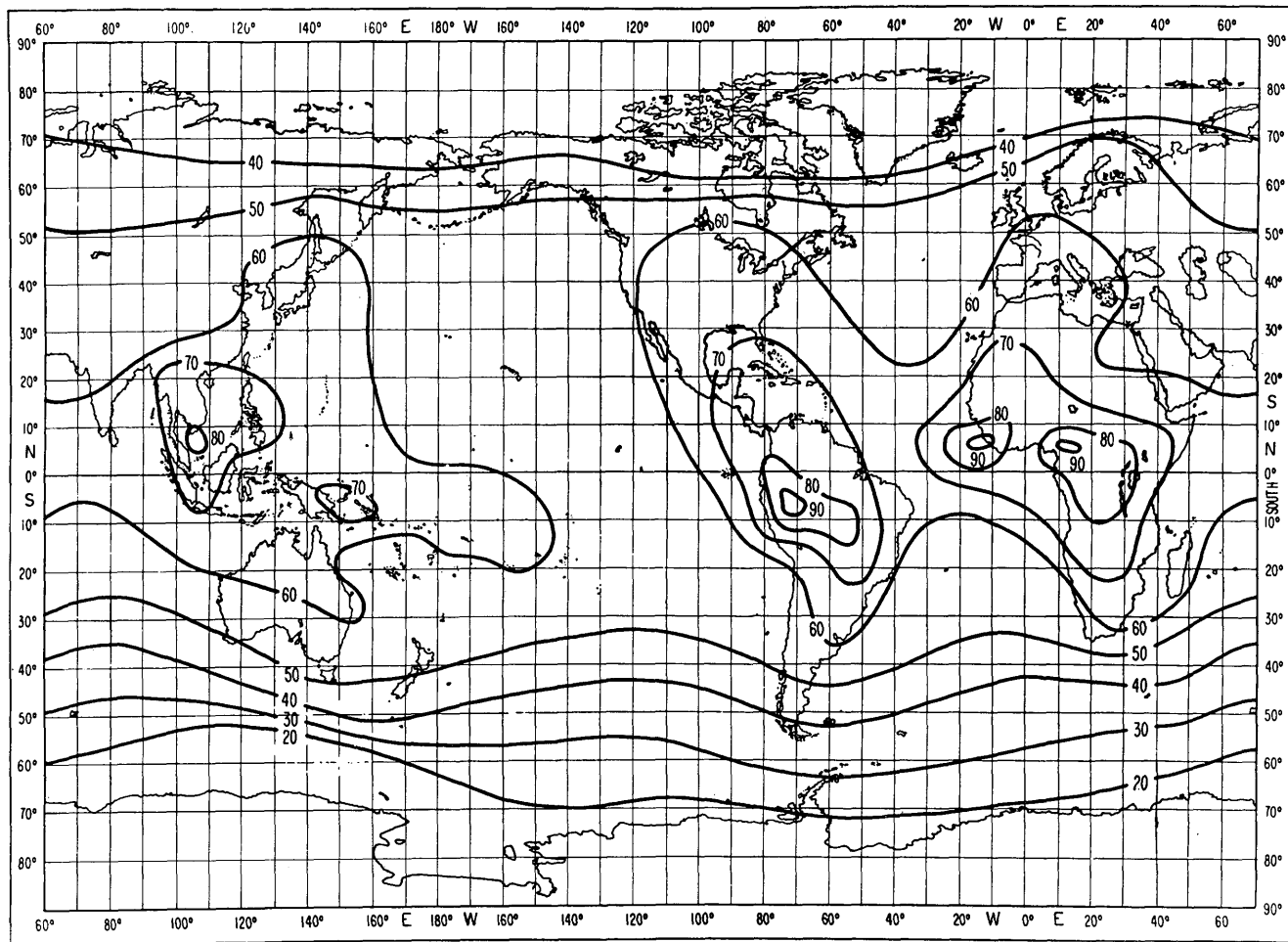
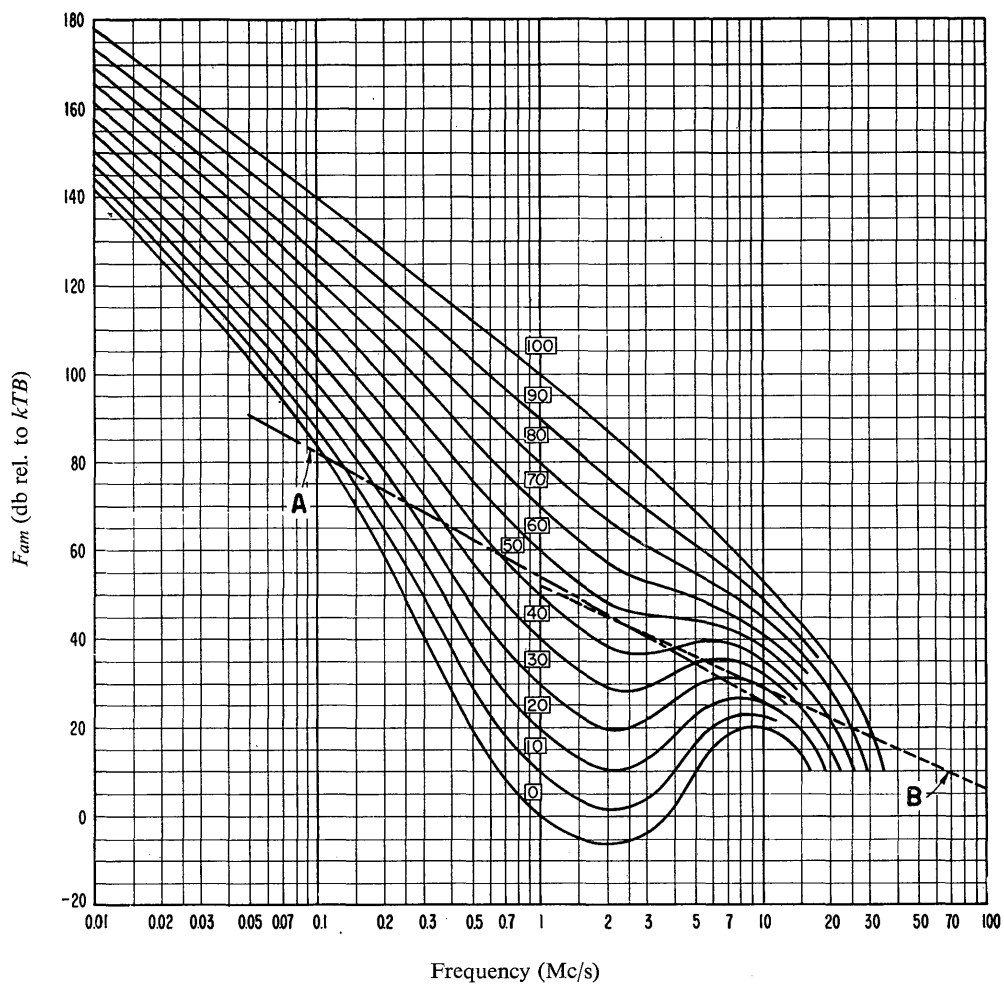


FIGURE 20

*Expected values of radio noise F_a (db rel. to kTB) at 1 Mc/s, from 1600—2000 hrs,
for September, October and November*





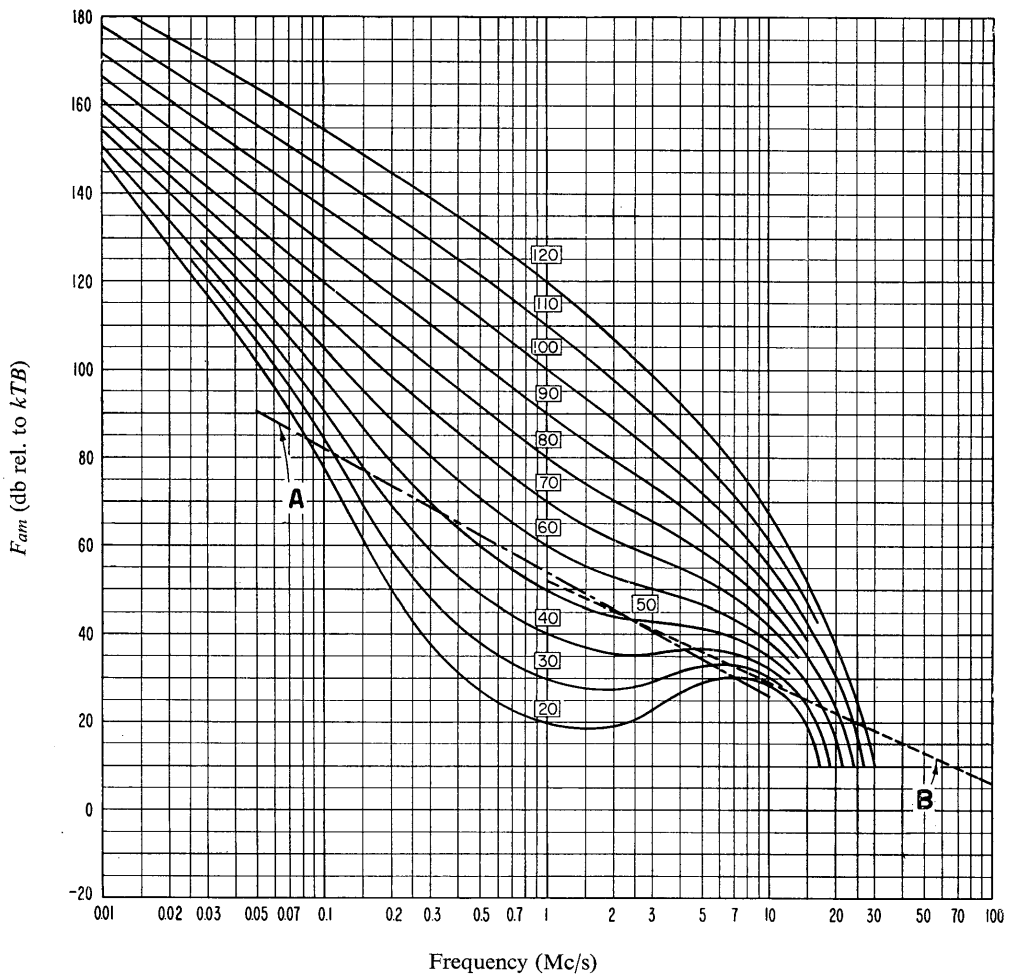
A — Expected values of man-made noise at a quiet receiving location.

B — Expected values of galactic radio-noise.

The figures in rectangles indicate the noise values at 1 Mc/s.

FIGURE 21

Median values of radio noise expected for a short vertical antenna for the time blocks :
0800—1200 hrs and 1200—1600 hrs for all seasons
0400—0800 hrs and 1600—2000 hrs for spring and summer



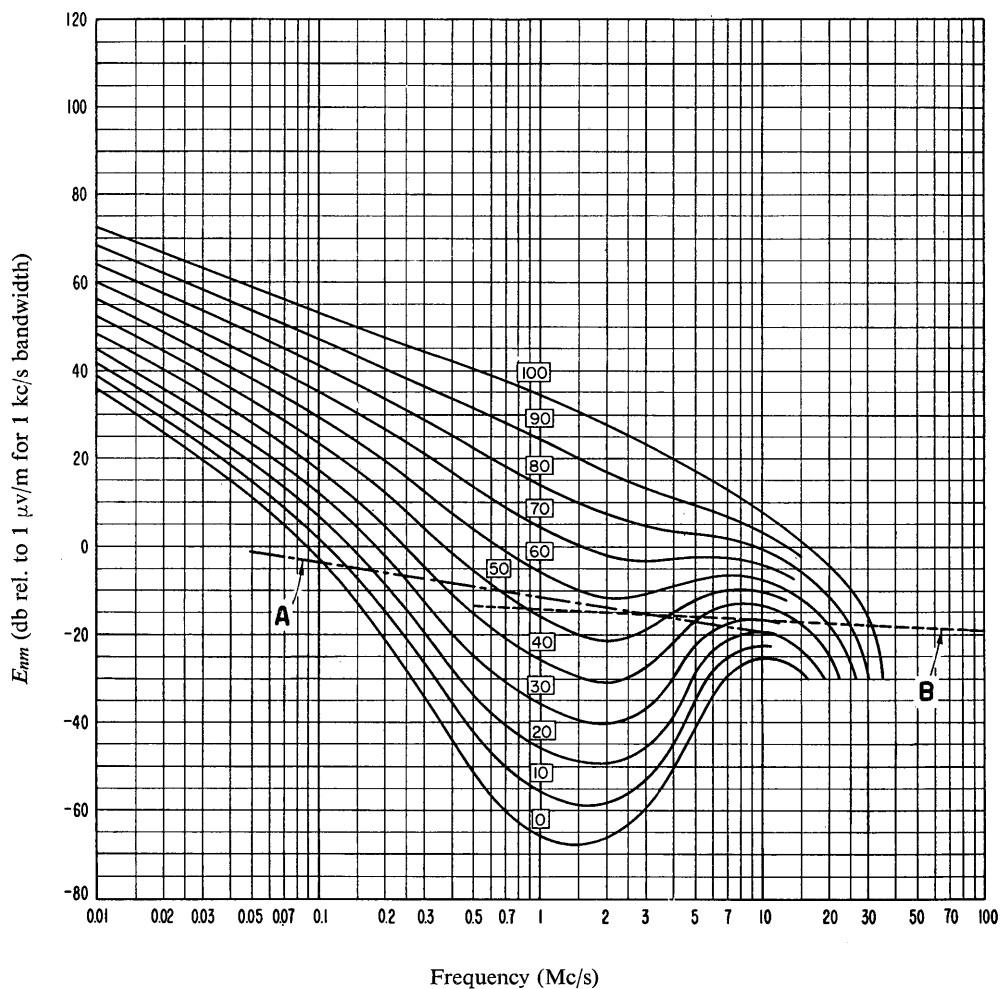
A — Expected values of man-made noise at a quiet receiving location.

B — Expected values of galactic radio-noise.

The figures in rectangles indicate the noise values at 1 Mc/s.

FIGURE 22

Median values of radio noise expected for a short vertical antenna for the time blocks :
 0000—0400 hrs and 2000—2400 hrs for all seasons
 0400—0800 hrs and 1600—2000 hrs for autumn and winter



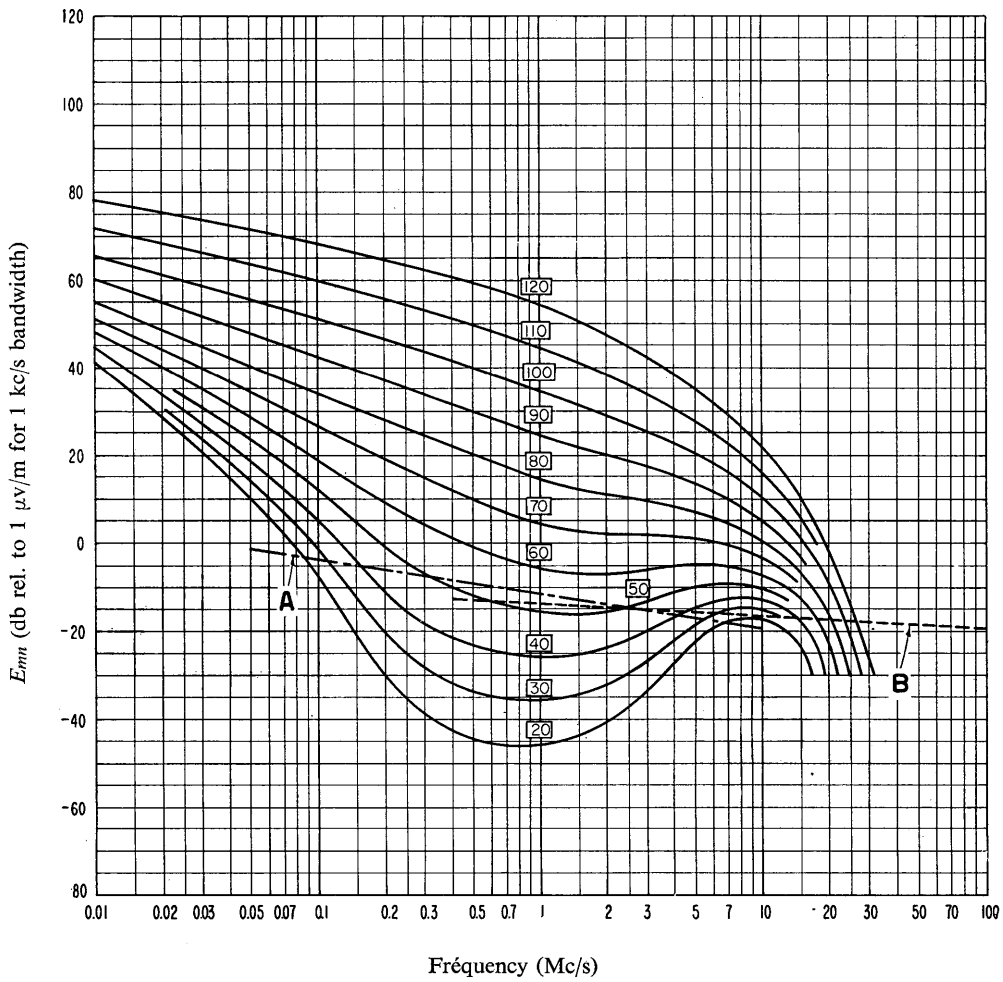
A — Expected values of man-made noise at a quiet receiving location.

B — Expected values of galactic radio-noise.

The figures in rectangles indicate the noise values at 1 Mc/s.

FIGURE 23

*Median values of radio noise expected for a short vertical antenna for the time blocks :
 0800—1200 hrs and 1200—1600 hrs for all seasons
 0400—0800 hrs and 1600—2000 hrs for spring and summer*



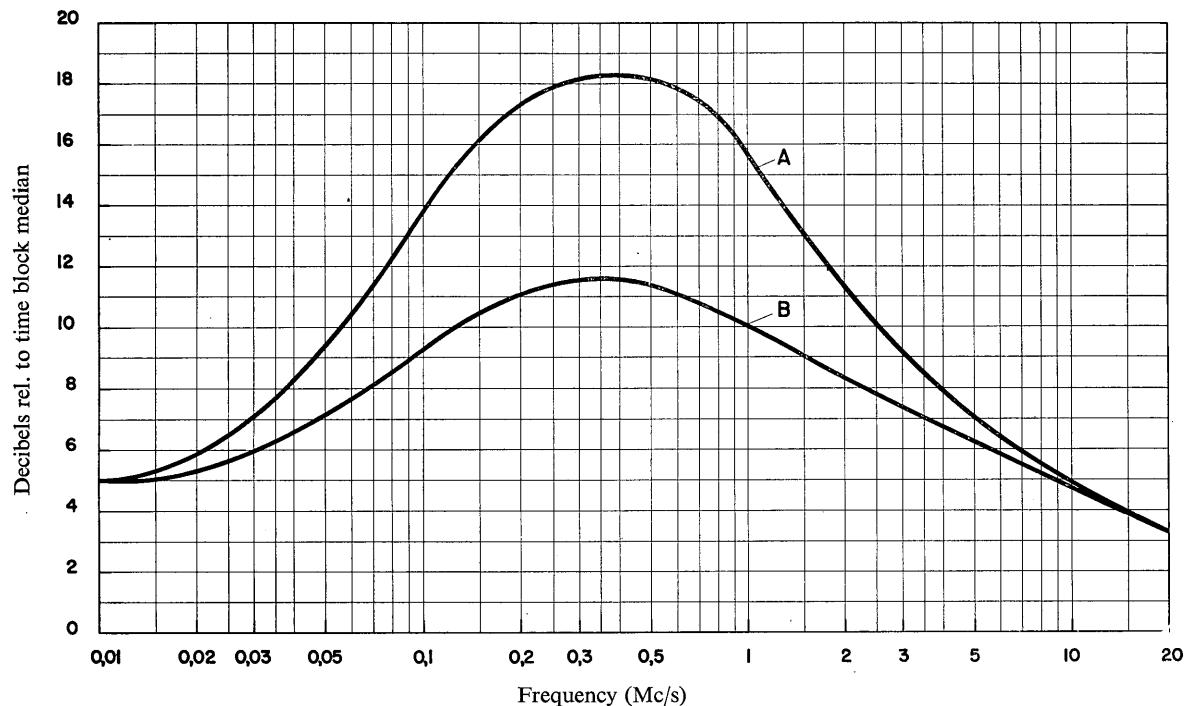
A — Expected values of man-made noise at a quiet receiving location.

B — Expected values of galactic radio-noise.

The figures in rectangles indicate the noise values at 1 Mc/s.

FIGURE 24

Median values of radio noise expected for a short vertical antenna for the time blocks :
 0000—0400 hrs and 2000—2400 hrs for all seasons
 0400—0800 hrs and 1600—2000 hrs for autumn and winter



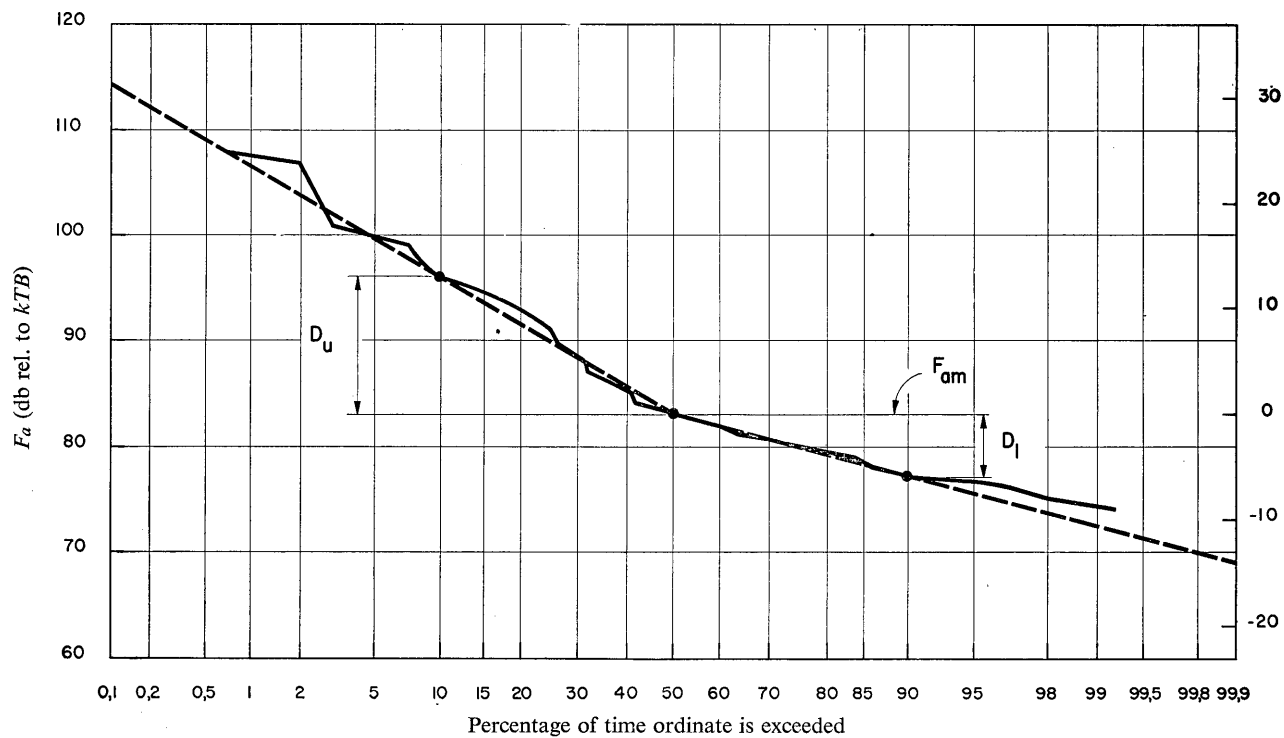
A — Ratio D_u (db) of the upper decile to the median for the time blocks:
 0400—0800 hrs 0800—1200 hrs
 1200—1600 hrs 1600—2000 hrs

B — Ratio D_u (db) of the upper decile to the median for the time blocks:
 0000—0400 hrs
 2000—2400 hrs

and ratio D_l (db) of the median to the lower decile for all time blocks.

FIGURE 25

Variations from the time-block median radio-noise levels

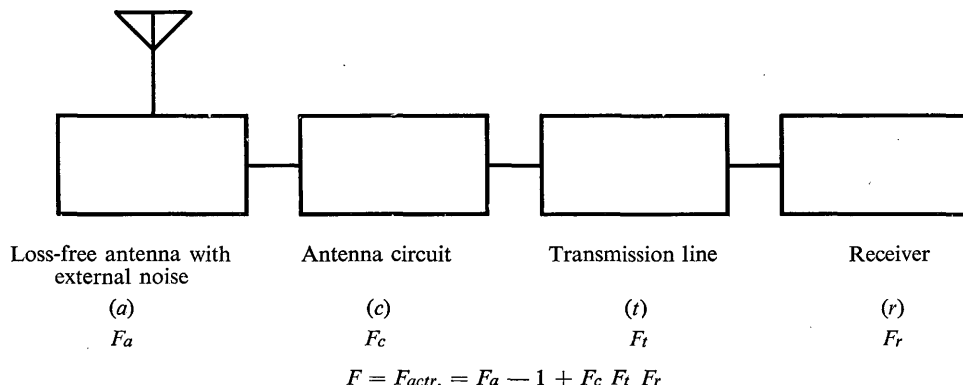


R.m.s. noise (Equivalent field strength for a vertically polarized ground-wave)
(db rel. to $1 \mu V/m$) for a 1 kc/s bandwidth.

FIGURE 26

Typical distribution of hourly medians

*Front Royal, Virginia, 135 kc/s, for the time block 1200—1600 hrs
September, October and November 1952*



$$F = F_{actr.} = F_a - 1 + F_c F_t F_r$$

FIGURE 27

Network for the definition of F , the effective receiver noise figure

REPORT No. 138 *

MEASUREMENT OF FIELD STRENGTH, POWER FLUX DENSITY (FIELD INTENSITY), RADIATED POWER, AVAILABLE POWER FROM THE RECEIVING ANTENNA AND THE TRANSMISSION LOSS

(Study Group No. V)

(Los Angeles, 1959)

1. Introduction.

This report is submitted with the intent of collecting in one paper the available pertinent information on Question No. 8, which was originally formulated at the Stockholm Conference of 1948. Since that time it has become apparent that for many purposes the measurement of parameters other than field strength have come into use, particularly for the description of the performance of complete systems. These parameters are power flux density (field intensity), available power from the receiving antenna and transmission loss **. The relations between these parameters are given in the Annex.

2. Purpose of Measurements.

Measurements of the above parameters are generally made for one of several purposes:

- 2.1 to determine the adequacy of the radio signal for a given service;
- 2.2 to determine the interfering effects of an emission;
- 2.3 to observe propagation phenomena, either for use in communication studies or to gain information of value to other physical studies;

* This report which replaces Recommendations Nos. 60, 61, 63, 65, 112, 113, 171 and Reports Nos. 48, 49 and 50, was adopted by correspondence without reservation (see page 9).

** Further discussion of the concept of transmission loss is given in Recommendation No. 241 and Report No. 112.

2.4 to check the strength of unwanted radiations of any waveshape arising from equipment which produces electromagnetic energy not intended to carry information and also to assess the efficiency of devices for the suppression of such radiation.

3. Antennae used for the Measurements.

The measurement of field strength may be made with any kind of receiving antenna but below approximately 30 Mc/s either loop or rod antennae are generally used on field strength sets [7, 8, 9]. The loop antennae are balanced and/or shielded to reduce electric field pick-up. Present general practice is to use an unbalanced loop with an electric shield split at the top. Most loops are multiturn, although some instruments employ single turn loops. Rod antennae cannot be effectively shielded from magnetic fields and in this frequency range are normally operated in an unbalanced manner with the rest of the instrument and power supply acting as ground.

Above about 30 Mc/s half-wave dipoles [7, 8, 9] are generally employed, although they are sometimes used in portable field strength equipment as low as 18 Mc/s and for recordings of field strength at fixed locations at much lower frequencies. At these frequencies, when grazing incidence at the ground is involved, propagation is normally independent of polarization. However, certain noise and interference measurement procedures are in use [1, 2, 3, 4, 13, 15] in which very close spacings are employed and arbitrary standards are normally required. Even then complications arise due to the fast rate of decay of the fields in the near-in region. Measurements so made may not be representative of the actual fields at greater distances and this type of procedure should be avoided if at all possible, except where it simulates the actual physical situation encountered in practice.

The measurement of the available power in the same receiving antenna, as is used in the radio system under test, will often provide a more directly useful result than would be provided by the use of a simple standard antenna, particularly in view of the fact that the received field will often be so complex that it will be most difficult to calculate the performance of the actual system in terms of field strength measurements made with simple dipole antennas.

For the measurement of weak electromagnetic fields, directional antenna arrays may be required.

4. Effects of the Environment on the Measurements.

Field strength or available power measurements should, in general, be made with the receiving antenna in the same location in which it will be used in practice. In the case of a broadcast system the performance is substantially affected by the presence of trees, buildings, overhead wires, etc. and it is important that such environmental factors should not be avoided in the measurements. A broadcast system is best evaluated by measurements made at a series of receiving locations systematically chosen by the method described in Report No. 142.

However, in the special case of field strength measurements made for the purpose of determining the radiated power or directivity of a transmitting antenna, it is desirable to use carefully selected sites with a minimum of disturbing environmental factors so that the values of the transmission loss or inverse distance field may be determined with greater accuracy.

In selecting a site for making measurements the following factors should be kept in mind:

4.1 The radio frequency fields at VHF and UHF may be distorted by wooden poles or other dielectrics as well as by conductors. If either the radiator or receiver is housed in a building for protection from the weather, this structure should be made preferably from materials of low dielectric constant which will not absorb water. Certain plastic materials have been found suitable in this respect. Where possible, measurements should be made with and without the structure to determine its effect. If there are buildings at the field strength set location, the ends of the receiving antennae should be as far as possible from the walls.

4.2 At all frequencies, the effects of overhead wires, cables or other conductors must be considered, and the receiving antenna should, if possible, be located at a distance of at least several times the height of the object from the disturbing object in areas of good ground conductivity and even further away in areas of poor conductivity. If a loop receiving antenna is used, the presence of such disturbing influences may often be detected from observations of the direction of arrival of the signal or from the poor definition of the nulls in the directional receiving pattern. If it is required to investigate nulls in a radiation pattern, special precautions may be necessary since a long power or communications line may conduct energy into the area of the null region where measurements are being made.

4.3 At frequencies above a few megacycles disturbing effects from underground cables generally do not have to be considered, but at frequencies much below 2 Mc/s such cables can cause appreciable errors in field strength measurements made near them even when the cables are buried a few metres. Very long underground cables (or cables connecting to overhead lines) are especially to be avoided. Fortunately, the disturbing fields are generally the induction fields and the effect of the cables can be determined by measuring at a number of locations at different distances away from the cables to determine the rate of attenuation of field strength. In regions of very poor ground conductivity these cables can be very troublesome and the effects may be complicated by directional patterns.

4.4 Vertically polarized fields in the VHF and UHF bands may be greatly affected by the ground conditions. If the source antenna and the field strength measuring antenna are horizontally polarized and close to the ground and either one is raised, the fields will tend to rise almost linearly with height until a maximum is approached and then the field will vary cyclically as the antenna is further raised. With vertically polarized antennae, however, the fields will remain substantially the same until a certain height is reached, and then there will be cyclic variations. The height range of relatively constant field will vary almost inversely with frequency and almost directly with dielectric constant, except where conductivity is high as in the case of sea water. For example, a vertically polarized field at 40 Mc/s is fairly constant with height up to about 5 metres over ordinary land; however, measurements over fresh water show that the field is constant to a considerably greater height. Failure to appreciate this phenomenon can lead to some serious errors in evaluation.

4.5 The disturbing effects may be different for different kinds of equipment; for example, movement of the operator in the vicinity of a field strength set with a loop antenna has little influence, but if a rod antenna is used the effect may be considerable.

4.6 It is shown in the Annex that it is preferable in some cases to measure either the field strength or the propagation loss rather than the transmission loss since these parameters are more nearly independent of the effects of the receiving antenna height or other environmental factors.

5. Polarization Effects.

At low frequencies vertically polarized waves are of almost exclusive interest except for sky-wave reception where horizontal polarization may be used. So far as ground-wave propagation is concerned, the polarization continues as radiated, except for minor wave-front tilt. However, for ionospheric reflections the received signal is a mixture of vertical and horizontal polarization [10] except for certain frequencies and distances. Thus, a loop receiving antenna will not exhibit normal directional characteristics with reflected ionospheric signals.

Above about 30 Mc/s, both polarizations are useful for transmission purposes, since the antennae are located an appreciable fraction of a wavelength or more above ground and absorption of the horizontal component by the ground is not a serious problem. There is little change in the polarization whether the signal is propagated over long distances via the troposphere or over short distances along the ground. However, conductors and other bodies near the transmitter or receiver may absorb one polarization and re-radiate or scatter an appreciable component of the other. Many sources may radiate both types of polarization. In addition, harmonic and other spurious radiation may be polarized differently from the fundamental as well as have maxima and minima at different locations from those of the fundamental.

6. Units of measurement.

Field strengths are usually measured in volts per metre or convenient submultiples thereof. This unit is strictly applicable only to the electric component of the field, but it is also generally used for expressing measurements of the magnetic component, especially for radiation fields in free space where the energies associated with both components are equal. Alternatively, at frequencies exceeding 1000 Mc/s, the power flux density (field intensity) may be measured in watts (or submultiples) per square metre.

If the emissions being measured have a bandwidth greater than that of the field strength set, consideration must be given to the effect of this factor on the measurements. For impulsive noise with widely spaced impulses and a uniform energy distribution throughout the part of the spectrum under consideration, the peak voltage will be a direct linear function of bandwidth and this leads to the unit of microvolts per metre per kilocycle (or microvolts per metre in a kilocycle band) [1, 3]. The concept of transmission loss is very useful for certain systems and propagation studies [16]. The transmission loss is defined as the ratio in decibels of the transmitting antenna power input to the available power output from the receiving antenna. The unit employed is the decibel.

7. Accuracy and repeatability of the measurements.

From the discussion in the Annex it is observed that the measurement of all the quantities under consideration here involves the determination both of the open circuit voltage in the receiving antenna as well as either the effective length, or the radiation resistance. The accuracy of determination of the latter two factors will depend upon the nature of the antenna and especially its environment, but, under ideal conditions such errors should be negligible compared to the error in measuring the open circuit voltage. The feasible absolute accuracy of measurement of the open circuit voltage is probably somewhat better than is shown in the following table:

Frequency band	Accuracy of measurement ($\pm$ db)	Minimum field strength at which this accuracy is obtained (μ V/m)
10 – 30 kc/s	2	10*
30 – 300 kc/s	2	5*
300 – 3 000 kc/s	2	2*
3 – 30 Mc/s	2	2*
30 – 300 Mc/s	2	2
300 – 3 000 Mc/s	3	5**
3 000 – 30 000 Mc/s	5	10**

* The minimum values will be somewhat higher for field strength sets with loop antennae.

** 1 μ V/m corresponds to 2.7×10^{-15} watts/sq.m.



Under the special conditions encountered at monitoring stations, some improvement of the accuracy figure should be obtainable at considerably lower minimum field strengths. Recommendation No. 181 covers these requirements. When measuring noise and interference of an impulsive nature lower accuracies may, in general, be tolerated [1, 3, 13].

The relative accuracy or repeatability of the measurements will usually be substantially greater than their absolute accuracy, provided the radiation source being measured remains constant. However, certain types of radiation sources, such as the leakage from a signal generator, harmonics and other spurious outputs from transmitters, oscillator radiation from receivers, radiation in the null of a directional antenna, etc., may vary substantially with time, and this may result in apparent inaccuracies of measurement which, in reality are simply due to a lack of stability of the quantity being measured.

8. Field strength set circuitry (1), (2), (7).

The signal delivered to the field strength set may vary from a fraction of a microvolt to several volts and the design must be such as to avoid errors due to overloading and cross modulation in the early stages. At least one tuned circuit before the first tube and an RF attenuator are generally employed and are followed by a mixer and amplifier having suitable gain and bandwidth. A calibrated IF attenuator may precede the IF amplifier chain, but sometimes change of bias to the IF tubes is used to provide the required attenuation. The IF amplifier drives the detector and metering circuits. In some cases preset switching of measuring circuits by coaxial relays may speed up measurements.

Many sets are designed to provide an approximately logarithmic input/output characteristic, which is very useful when measuring or recording fading signals, etc. The required characteristic is obtained either by shaping the pole pieces of the output meter or, more frequently by the use of suitably designed automatic gain control of the IF amplifier.

9. Self-calibration techniques.

A few sets depend solely on their constructional stability without provisions for self-calibration. Some check may be obtained in these sets by noting the tube noise indication. This approach is not too satisfactory at the present state of the art unless signal generators are available for frequent checking. In general, self-calibration is provided by one of the following methods:

9.1 continuously variable frequency calibration oscillator with thermo-couple amplitude check. This probably has the best long term stability;

9.2 continuously variable frequency calibration oscillator with crystal diode, tube diode, or grid current indicator. The latter is generally unsatisfactory because of errors which often occur in its use;

9.3 fixed frequency calibration oscillator for setting field strengths set sensitivity at one or more places in each band. This method has the difficulty that changes in receiver alignment can cause serious errors at other frequencies unless some further check is employed such as use of an impulse generator for extrapolation to other frequencies;

9.4 noise diode (especially for noise measuring sets). This is a compact and convenient type of calibrator for noise measurements, or rough measurements, but is not wholly satisfactory, as presently used for other kinds of measurement, both because of its own accuracy problems and the effect of receiver bandwidth. The observed instabilities may be more related

to the portable nature of the equipment in which this method is used rather than to any fundamental inherent errors of a noise diode;

9.5 impulse generator (especially for noise meters). This type of source is preferable for impulse noise measurements, but it has the limitation that, if changes in receiver bandwidth occur, the calibration may be unsatisfactory for measurements other than impulse noise;

9.6 built-in signal generator and signal generator attenuator. This is probably the best method but generally results in increased cost and weight, especially since very good shielding and filtering are required.

The self-calibration facilities are generally satisfactory over limited periods of time and the instruments should be periodically checked against external standards which should, whenever possible, provide the same type of waveform as the signal to be measured. It is well to make frequent checks until the stability of the particular instrument is determined. These checks should be made at various levels to check attenuators as well as signal sources and should include checks of the interpolation meter linearity. During these checks, it is generally well to check the alignment with a sweep oscillator at several levels. Misalignment may cause operating difficulties, affect attenuator ratios, affect response on broadband signals, and cause regenerative effects resulting in bandwidth changes with signal level. Occasionally, the regenerative effects may be due to the feeding back of an intermediate frequency harmonic to earlier stages and may result in a rather sharp change in sensitivity as the frequency is changed. Similar abnormal effects may occur in sets in which there is unwanted coupling between the calibrating oscillator and the rest of the set.

10. External methods of calibration.

Of the external methods of calibration, two have found wide application. At frequencies below 20 Mc/s, it is possible to calibrate a field strength set having a loop antenna by the establishment of an accurately calculable voltage induced by a second coaxial loop of known dimensions carrying a known current [5, 8, 9, 14]. In the other method, which is particularly useful at the higher frequencies and which is applicable with either loop or rod antennae, calibration is effected by means of a known radiation field using horizontally polarized waves, [6, 8, 9, 14]. For both methods, an overall calibration of the field strength set, including the receiving antenna, is obtained under conditions similar to those likely to be encountered in the subsequent use of the set.

11. Power supplies.

All power supplies, including those for the tube heaters should be adequately stabilized. and the primary power source should provide sufficient voltage at all times to ensure proper operation of the stabilizing apparatus.

12. Special Precautions (7).

Before measurement is made:

12.1 RF and IF attenuators should be checked against each other, if possible, and against the indicating metre scale.

12.2 When measuring strong signals or a weak signal in the presence of strong signals, e.g. harmonic or other spurious emissions, precautions should be taken to avoid overloading the early stages of the set. In the latter case, the use of filters at the set input is recommended.

13. Parameters Suitable for Measurement Purposes.

For continuous wave signals, the type of measurement made (average, peak, etc.) is relatively unimportant. However, with complex waveforms, the indicated value of the field strength or available power will be influenced by the characteristics of the measuring instrument, i.e., its detector characteristics, bandwidth, dynamic range, integration time, etc. Thus, the equipment must be designed to measure a parameter that is suitable for the evaluation of the type of waveform that is present. With a coherent signal of known waveform, one parameter is usually sufficient; but with an incoherent function such as atmospheric noise, two or more parameters are often necessary for an adequate description.

13.1 *Average Value Measurement.*

The average value of a signal is given by the receiver when the circuit following a linear envelope detector is designed to average the detector output voltage over a time interval long enough for rapid variations to be imperceptible. The average value is generally preferred for many modulated emissions, including amplitude and frequency modulated telephony (A3 and F3). It is also used for on-off keyed telegraphy (A1 or A2) where the key down position can be maintained during measurement. It may also be used to measure the peak value on signals having a high duty factor for pulses at the peak value, such a TV visual emissions having positive synchronizing signals. The peak value will of course be derived from the average value by the addition of a predetermined correction factor. It is also used as one of the parameters in evaluating atmospheric noise and other interference phenomena.

13.2 *Peak Value Measurement.*

The peak value of a signal is given by the receiver when the detector circuit is designed to give an output corresponding to the maximum instantaneous voltage of the signal. This may be measured by one of the following types of circuits:

- Cathode ray oscillograph at the output of the RF or IF amplifier.
- Slide back detector with audible or visual indicator to show when the threshold has been exceeded.
- Peak detector with slave rectifier having a memory and a manual or automatic zero resetting device.

Peak measurements are particularly suitable for low duty cycle signals, including impulsive interference, but are often subject to greater fluctuations than the quasi-peak or average values. If the bandwidth of the signal to be measured is greater than that of the field strength set, then the peak value of the emission as measured by the detector is affected. While measurements made at one bandwidth can be corrected to another bandwidth for certain simple types of emission, this is not the typical situation and bandwidth standardization for the sets is necessary if comparisons are to be made. Under such conditions, the bandwidth of the field strength set should be stated. Similar bandwidth considerations may apply as in quasi-peak measurements, and reference should be made to Table I in § 13.3 for standard bandwidths.

13.3 *Quasi-Peak Measurement.*

The quasi-peak value is that measured when the detector output is weighted by adjustment of its charge and discharge time constants T_c and T_d and the mechanical time constant of the indicating meter T_m . Because of its convenience, the quasi-peak value is generally used for types of emission which are keyed or pulsed or for which the average value varies with modulation level.

It is generally appropriate for impulsive interference measurements and, if the charge and discharge time constants are suitably chosen, quasi-peak measurements can provide a direct indication of the audible effect produced by interfering signals of any shape on modulated transmissions such as telephony.

As regards bandwidth, similar considerations to those of peak measurements apply, and care must be used in selecting both the bandwidth and the charge and discharge time constants to suit the type of emission being measured and to prevent overloading the set. Only a few sets of standard constants have been recognized by qualified organizations, and these are listed in the table below:

TABLE I

Frequency Range (Mc/s)	Bandwidth at 6 db down (kc/s)	Charge time constant (T_c) (sec.)	Discharge time constant (T_d) (sec.)	Mechanical time constant (T_m) (sec.)
0.015–0.15	Variable (0.08–0.8) **	0.001 **	0.600 **	
0.15–30	9 * Variable (1–12) **	0.001	0.160 0.600 **	0.160 *
25–300	120 * 150 **	0.001	0.550 * 0.600 **	0.1 *

* C.I.S.P.R. (1).

** A.S.A. (2).

Note: The constants without asterisks are used by both organizations.

13.4 *R.m.s. voltage.*

The r.m.s. voltage [17] is measured by means of a thermocouple or electronic squaring circuit in conjunction with a suitable averaging circuit. It provides a direct measurement of the average power received in the bandwidth of the measuring instrument. For emissions with a uniform frequency spectrum, the r.m.s. voltage is proportional to the square root of the bandwidth (the average power is proportional to the bandwidth). The r.m.s. value is suitable for the measurement of many types of broadband phenomena, but is particularly useful in the measurement of atmospheric noise [18]. Since the squared values have a wider range of fluctuation than the original phenomenon, a wider dynamic range and longer time constant are required. With atmospherics, a time constant of 500 seconds has been found satisfactory.

13.5 *Average logarithm.*

The average logarithm is obtained by inserting a logarithmic amplifier between the detector and the averaging circuit. This type of measurement, in conjunction with measurements of the average and r.m.s. values, provides information on the character or interference potential of noise. For atmospheric noise, these three parameters provide a means of determining the complete amplitude-probability distribution [11, 17].

13.6 *Statistical measurement.*

It is frequently of interest to determine the statistical variations of field strength with time. The variation of the instantaneous values may be of interest of the variations of the average value of any of the above parameters may be of interest. The latter can be measured by means of time

totalizers with several preset thresholds, so that the total time above each threshold is indicated on motor driven counters. These counters are read at the end of any desired period of time.

When the variations of the instantaneous values are of interest, electronic counting circuits are used that will respond to the instantaneous IF or detector output. By means of suitable gating and threshold circuits, the amplitude-probability distribution of these values can be obtained. The complete amplitude-probability distribution has been found useful in evaluating the interference, particularly that of atmospheric noise, to the reception of various types of signals [12].

14. Parameters to be measured for different types of emission.

The following table is a summary of suggested parameters for the measurement of various emissions, as classified in Article 2, Chapter II of the Radio Regulations of Atlantic City (1947).

TABLE II

Type of Emission	Parameter Measured (see Section 12)
A0, A2, A3, A4, A9 F0, F1, F2, F3, F4, F5, F9 * A1 (key down) A5 (negative sync.) **	Average
A1, A3 a, A3 b, A9 c	Quasi-peak
A5 (positive sync.) P0 and other pulsed emissions	Quasi-peak or peak

* Care must be exercised that the bandwidth of the field strength meter is adequate to pass the FM emissions.

** It is usual to define the field strength of a negative sync. TV signal as the peak-white value. This value can be derived from the average value, if the waveform being radiated at the time the measurement is made is known.

15. Radiated power.

The radiated power from a transmitting antenna may be determined either as:

15.1 the input power to the transmitting antenna diminished by the loss in its antenna circuit, or;

15.2 the measured available power in a lossless receiving antenna increased by the transmission loss, the reception being carried out at some carefully chosen location where the transmission loss can be calculated.

At the lower frequencies, the radiated power is often determined by measuring an unattenuated inverse distance field, i.e. the radiation field expected at a unit distance on a perfectly conducting plane surface. Then the radiated power may be determined by calculations which allow for the radiation characteristics of the particular antenna under consideration.

ANNEX

THE RELATIONS BETWEEN FIELD STRENGTH, POWER FLUX DENSITY (FIELD INTENSITY)
AND THE AVAILABLE POWER IN THE RECEIVING ANTENNA

Let e denote the field strength expressed in volts per metre. The power flux density (field intensity), f , expressed in watts per square metre is given by:

$$f = e^2/z \quad (1)$$

where z is the characteristic impedance of the medium in which the measurement is made. In air or free space $z \approx 120 \pi$.

The absorbing area of a receiving antenna with gain, g_r , relative to an isotropic antenna, may be expressed:

$$a_e = \lambda^2 g_r r_f / 4 \pi r \quad (2)$$

where λ is the wavelength in the medium, r is the radiation resistance of the antenna while r_f is the radiation resistance the antenna would have if it were in free space. Combining equations (1) and (2), we find the following formula for the available power, p'_a , from a lossless receiving antenna:

$$p'_a = (e^2 \lambda^2 g_r r_f) / 4 \pi z r = v^2 / 4 r \quad (3)$$

The v in equation (3) denotes the open circuit voltage induced in the receiving antenna. Solving equation (3) for v , we find the following general relation between the field strength and the open circuit voltage for an antenna with gain, g_r , and free space radiation resistance, r_f :

$$v = e \sqrt{\lambda^2 g_r r_f / \pi z} = e l \quad (4)$$

We see by equation (4) that the measurement of the field strength involves essentially two steps:

- the measurement of the open circuit voltage, and
- the determination, either by calculation or measurement, of the effective length, l , of the receiving antenna, [5, 6, 15 and 19].

Similarly, we see by equation (3), that the measurement of the available power also involves two steps:

- the measurement of the open circuit voltage, and
- the determination, either by calculation or measurement, of the radiation resistance of the receiving antenna. Note, however, that the radiation resistance, and, thus, the available power, depends upon the height of the receiving antenna above the ground, whereas its effective length is, at least to a good first approximation, independent of this height or of other environmental influences. This is one of the advantages of measuring the field strength rather than the available power in some applications. Note that the propagation loss L_p may be so defined that it also is independent of such effects of the local environment on the antenna impedance.*

* See Report No. 112 for a more complete discussion of propagation loss.

BIBLIOGRAPHY

1. Specification for C.I.S.P.R. Radio Interference Measuring Apparatus for the Frequency Range 0.15 Mc/s to 30 Mc/s. *C.I.S.P.R. Report No. 302*.
Specification for C.I.S.P.R. Radio Interference Measuring Apparatus for the Frequency Range 25 to 300 Mc/s. *C.I.S.P.R. Report No. 303*.
2. Proposed American Standard Specifications for Radio Noise and Field Strength Meters
ASA C 63.2 – 0.015 to 30 Mc/s
ASA C 63.5 – 25 to 400 Mc/s
3. Proposed American Standard on Methods of Measurement of Radio Influence Voltage and Radio Influence Field (Radio Noise)
ASA C 63.4 – 0.015 Mc/s to 25 Mc/s
ASA C 63.3 – 25 Mc/s to 400 Mc/s
4. *I.E.C. Report Sc.*, 12-1.
5. GREENE, F. M. Calibration of Commercial Radio Strength Meters at the National Bureau of Standards. *NBS Circular*, 517 (December, 1951).
6. MCPETRIE, J. S. and SAXTON, J. A. Theory and Experimental Confirmation of Calibration of Field-Strength Measuring Sets by Radiation. *Journal I.E.E.*, 88, Part III, 11 (1941).
7. CHAPIN, E. Field Strength Measurements. *F.C.C. Report L.D. 6.3.1*.
8. TERMAN, F. E. and PETTIT, J. M. *Electronic Measurements*, McGraw-Hill, (1951), Chapter XI.
9. SMITH-ROSE, R. L. Radio Field-Strength Measurement. *Proc. I.E.E. (Radio and Comm.)*, 96, Part III (January 1949).
10. SMITH, W. B. Recording Sky-Wave Signals from Broadcast Stations. *Electronics*, 21, 112 (November 1945).
11. CRICHLAW, W. Q. and SPAULDING, A. D. A Graphical Method of Obtaining Amplitude-probability Distribution from Statistical Moments of Atmospheric Radio Noise, presented at Joint Meeting URSI-IRE, (October 20-22, 1958), at Penn. State University.
12. WATT, A. D. *et al.* Performance of Some Radio Systems in the Presence of Thermal and Atmospheric Noise. *NBS Journ. of Research*, B (July 1959).
13. Recommended Practice for Measurement of Field Intensity above 300 Mc/s from Radio-Frequency Industrial, Scientific and Medical Equipments. *A.I.E.E.*, 950 (April 1951).
14. WIND, M. *Handbook of Electronic Measurements*, Vol. II, Chapter VIII, Polytechnic Institute of Brooklyn, Inter-science Publishers.
15. Standards on Radio Wave Propagation Measuring Methods. *Supplement to Proc. I.R.E.*, Vol. 30, 7, Part II (1942).
16. NORTON, K. A. Transmission Loss in Radio Propagation (I and II):
Part I — *Proc. I.R.E.*, 41 (Jan. 1953).
Part II — *N.B.S. Technical Note No. 12*, (June 1959), Office of Technical Services, U.S. Department of Commerce, Washington 25. D.C.
17. *Proc. U.R.S.I. XIIth General Assembly*, Boulder, Colo.; Vol. XI, Part 4, Commission IV.
— Report No. 254: What are the most readily measured characteristics of terrestrial radio noise from which the interference to different types of communications systems can be determined, p. 9.
— Recommendation No. 1 and Annex to Recommendation No. 1: Measurement of atmospheric noise, p. 99.
18. C.C.I.R. Report No. 65. Revision of Atmospheric Radio Noise Data.
19. DIAMOND, H., NORTON, K. A. and LAPHAM, E. G. On the Accuracy of Radio Field-Intensity Measurement at Broadcast Frequencies. *Jour. of Res. of the NBS*, 21, 795-818 (December, 1938).
20. NORTON, K. A. System Loss in Radio Wave Propagation. *NBS Journ. of Res.*, D (July 1959).

REPORT No. 139 *

DETERMINATION OF THE ELECTRICAL CHARACTERISTICS OF THE SURFACE OF THE EARTH

(Question No. 135 (V))

(Los Angeles, 1959)

1. Introduction.

Question No. 135 (V) was adopted for study as a new Question at the VIIIth Plenary Assembly at Warsaw. This report discusses the physical factors upon which the characteristics depend, reviews the methods which have been used to determine the ground constants and assesses the value of these methods in connection with the calculation of radio propagation; a list of references to published literature on this subject is given at the end of this report.

2. The characteristics of the ground.

The electrical characteristics of the ground or other medium may be expressed by three constants, the permeability, the dielectric constant and the conductivity. The permeability of the ground relative to free space can be regarded as unity so that in propagation problems we are concerned only with the relative dielectric constant, ϵ and the conductivity σ . These two constants are associated together in their application to the propagation formulae by the expression for the complex dielectric constant:

$$\epsilon' = \epsilon - j(18 \cdot 10^{20} \sigma) / f$$

where σ is in e.m.u., f is the frequency in c/s. The relative importance of the two constants depends, therefore, upon the frequency as well as on the values of each. Although the values of ϵ and σ tend to vary together, from $\epsilon = 81$ and $\sigma = 4 \cdot 5 \times 10^{-11}$ for sea water to about $\epsilon = 5$ and $\sigma = 1 \times 10^{-15}$ for dry sand or rock, the relative values of the real and imaginary terms depend mainly on the frequency. In general, on land the conductivity is the only effective constant at frequencies below 500 kc/s. At 10 Mc/s, the two constants are of comparable importance, and at higher frequencies the dielectric constant predominates. Over sea only the conductivity is of importance except at microwave frequencies.

3. Factors determining the effective ground constants.

The effective values of the constants of the ground are determined not only by the nature of the soil but also by its moisture content and temperature, by the frequency, by the general geological structure of the ground and by the effective depth of penetration and lateral spread of the waves. The absorption of energy by vegetation, buildings and other objects on the surface must also be taken into consideration.

3.1 Nature of the soil.

Although it has been established by numerous measurements that the constants vary with the nature of the soil it seems probable that this variation may be due not so much to the chemical composition of the soil as to its ability to absorb and retain moisture. It has been shown that

* This Report was adopted by correspondence without reservation (see page 9).



loam, which normally has a conductivity of the order of 10^{-13} e.m.u., when dried can have a conductivity as low as 10^{-15} e.m.u. which is of the same order as that of granite.

3.2 *Moisture content.*

The moisture content of the ground is probably the major factor determining its electrical constants. Laboratory measurements have shown that as the moisture content is increased from a low value the constants increase, rapidly reaching their maximum values as the moisture content approaches the values normally found in such soils on site. At depths of one metre or more the wetness of the soil at a particular site seems to be substantially constant all the year round and, although it may increase during rain, the drainage of the soil and surface evaporation soon reduces it to its normal value after the rain has stopped. The moisture content of a particular soil may, however, vary considerably from one site to another due to differences in the general geological formation which provide better drainage in one case than another.

3.3 *Temperature.*

Laboratory measurements of the constants of samples of various types of soil have shown that the temperature coefficient of conductivity is of the order of 2% per degree centigrade while that of the dielectric constant is negligible and that at freezing point there is a large rapid change in both constants. Although these changes are appreciable it must be borne in mind that the range of temperature variation during the year decreases rapidly with depth so that temperature effects are likely to be important only at high frequencies where the penetration of the waves is small (see § 3.5) or when the ground is frozen to a considerable depth.

3.4 *Frequency.*

Laboratory measurements on soil samples show that there is a variation of the constants with frequency which depends markedly on the moisture content. It is noted, however, that the variation of conductivity is appreciable only at abnormally low values of moisture content and that the apparent change in dielectric constant may be due mainly to polarization effects. It is uncertain, therefore, whether, in practice, frequency has any substantial influence on the constants of homogeneous soil (see, however, § 3.6).

3.5 *General geological structure.*

The ground involved in over-land propagation is not usually homogeneous, so that the effective ground constants are determined by several different types of soil. It is, therefore, of great importance to have a complete knowledge of the general geological structure of the region concerned. The effective constants over an area or along a path are determined not only by the nature of the surface soils but also by that of the underlying strata. These lower strata may form part of the medium through which the waves travel or they may have an indirect effect by determining the water level in the upper strata.

3.6 *Penetration and spread of waves.*

The extent to which the lower strata influence the effective ground constants depends upon the depth of penetration of the radio energy. This in turn depends on the value of the constants and the frequency. If the depth of penetration, δ , is defined as that depth in which the wave has been attenuated to $1/e$ (or 37%) of its value at the surface, then over the frequency range 10 kc/s to 10 Mc/s, δ has the values shown in Table I. It will be seen that at frequencies of 10 Mc/s and above only the surface of the ground need be considered, but at lower frequencies, strata down to a depth of one hundred metres or more must be taken into account. It is particularly important to take account of the lower strata when the upper strata are of lower conductivity since in this case more energy penetrates to the lower levels than happens with an upper layer of higher conductivity.

The radio energy received at a point does not travel solely by the direct path from the transmitter but also by a large number of indirect paths distributed on either side of it. It is necessary, therefore, to consider the constants of the ground not only along the path itself but also over the area covered by the lateral spread of the wave paths. No definite limits can be put on this area but it has been suggested that it is effectively the first Fresnel half-wave zone, i.e. the ellipse having the transmitter and receiver positions as its foci and axes of $(D + \lambda/2)$ and $\sqrt{D\lambda}$ respectively, where D is the length of the direct path and λ is the wave-length.

3.7 *Energy absorption by surface objects.*

Although surface objects have no direct influence on the constants of the ground itself they can contribute appreciably to the attenuation of ground waves and the values of the ground constants used in propagation calculations may take account of the effects of such energy losses.

4. Methods of measuring ground constants.

The following methods have been used to determine one or both constants.

4.1 *Laboratory measurement of soil samples.*

The dielectric constant and conductivity of samples of soil are determined by measurements of the resistance and reactance of capacitor units containing the soil as the dielectric. This method has been used for measurements on sea water and a wide variety of soils, including rock, at frequencies mainly in the range 1 kc/s to 10 Mc/s.

4.2 *Probe method of ground resistivity measurement.*

The conductivity of the ground is obtained by measurements on site of the resistance between probes driven into the ground. The measurements are usually made with direct current using a system of four probes, a current being passed between one pair and the resultant potential difference being measured between the other pair. The depth to which the measurements are effective is determined by the spacing between the probes and the thickness of the surface layer of soil or the height of the water table can be determined by a series of measurements made at different spacings.

The conductivity has also been deduced from the measured mutual impedance between two parallel lines laid on, or just above, the surface of the ground and earthed at their ends.

4.3 *Wave tilt method**

The forward tilt of the electric force of a vertically polarized wave is measured in the field by using a rotatable dipole aerial and from it the conductivity is deduced. If additional measurements of the field components in other directions are made using a rotatable dipole, or two fixed serials in mutually perpendicular vertical planes, values for the dielectric constant can also be obtained. The method is suited mainly to the higher frequencies and has been used over the range 1 to 40 Mc/s.

It must be stressed that the method is essentially valid only for earth that is homogeneous in the horizontal direction. Therefore, in the case of considerable horizontal inhomogeneity of the earth, proper care should be exercised in applying this method.

* Note by the Director of the C.C.I.R. — Subsequent to the preparation of this Report in Los Angeles, the following additional information has been furnished by the Federal German Republic. "The wave-tilt method has been used in Germany with reliable results on frequencies down to 100 kc/s. Furthermore, this method has been used successfully to measure horizontal inhomogeneities of the surface of the earth. Errors however result if the measurements are made in the vicinity of areas where there are junctions of soils with widely differing conductivities, such as a transition from land to sea or from light soil to swampy ground."

4.4 *Ground wave attenuation measurement.*

Measurements are made of the attenuation with distance of waves propagated along the ground and the ground conductivity is deduced by the comparison of the results with propagation curves derived according to rigorous theories or semi-empirical methods regarded as acceptable in the case considered. The method is applicable at all frequencies.

4.5 *Attenuation with depth below the surface.*

The ground constants may also be determined by measuring the relative rate of attenuation of the field strength with a receiver as it is lowered below the surface of the earth in a well or other suitable hole. (Further details of this method are given in Doc. 130, Los Angeles, 1959, and in Radio Journal (U.S.S.R.), No. 2, 1959).

4.6 *Phase change measurements.*

The conductivity over homogeneous ground may also be deduced from measurements of the change of phase with distance of a ground-wave, the value of the constant being determined from the rate of change of the phase. This method, which has been used only at low frequencies, is found to be a more sensitive means of locating discontinuities in the ground than that provided by a attenuation measurement.

4.7 *By measurement of reflection coefficient.*

The reflection coefficient of the ground is measured in the field by methods involving normal incidence radiation. From the results both the dielectric constant and the conductivity can be deduced, though with less accuracy in the case of the latter. This method is only suitable at very high frequencies.

5. *Use of the methods in connection with propagation problems.*

From a study of the methods and of the factors affecting the ground constants it is clear that most of the methods do not give all the information required for propagation calculations and that in some cases an extensive series of measurements is involved.

For example, the laboratory measurements of soil samples may give accurate and detailed data on the constants of soil under its natural conditions but it is necessary that this sampling should be extensive both along the path of propagation and in depth. It is also necessary to have an accurate knowledge of the geological structure of the path in order to be able to use the data to assess the effective constants of the ground. This method is probably more suited to the investigation of the possible variations in the constants and the parameters on which they depend than to the determination of the characteristics of a particular path.

The ground resistivity method takes more account of the general structure of the ground, but only over a relatively small area. It is simple and convenient in practice and is probably the most suitable in cases where only the characteristics of the ground in the immediate vicinity of the transmitter or receiver are required. The effective constants to various depths are readily obtained but for the assessment of path attenuation, measurements at a number of points along the path would have to be made, the intervals between the points being determined by the vertical stratification of the ground.

The wave tilt method also takes account of the general structure of the ground around the point of measurement and gives the effective conductivity corresponding to the radio frequency used. The results may, however, be influenced to some extent by the ground over which the waves have travelled from the transmitter and by local surface or buried objects which distort the wave front. For the determination of path attenuation it would be necessary to make a series of measurements along the path, as with the resistivity method, and at the required radio frequency so that proper account may be taken of the lower strata. The method is not suitable at low frequencies because of the difficulty in measuring the small angles of tilt which occur. As mentioned before, difficulties of a fundamental character appear when using this method for earth with horizontal inhomogeneities.

The ground-wave attenuation method is one of the most comprehensive since it takes all factors into account. The results, however, give the mean value of the constants for the whole

path between transmitter and receiver and although an indication of any changes in the constants over the path can be obtained the detailed information is probably not so accurate as that given by the ground resistivity or wave tilt methods. Moreover, the results will only apply to the particular path used, or to one very similar, and seem to be of little value in predicting the constants over other paths.

The phase change method also takes all factors into account and, in addition, seems to be capable of giving more detailed information on inhomogeneous paths than can be obtained by the attenuation method. It has, however, the disadvantage of using very complex equipment.

The reflection coefficient method provides data which is applicable to only a small area of ground around the point of measurement and, since it can only be used at very high frequencies, the depth of ground involved is also very small.

In considering the suitability of the various methods account must be taken of the type of data and accuracy required, and the use to which the data is to be put. But whatever the purpose or method it is evident that, before the data is used, a careful study should be made of all available geological information.

6. Observation on C.C.I.R. Question No. 135 (V).

Question No. 135 (V) is in five parts. The first asks what is the most practical method for determining the equivalent ground constants of radio-communication services. Although, as already mentioned, the method used may depend upon the type of data required, any recommendation must be based mainly on practical experience, in which due consideration is given to such points as the portability of the equipment, measuring procedure, accuracy and effort involved.

The second part is concerned with the deduction of changes in the constants from corresponding changes in the field characteristics along the path. It has already been shown that such changes in constants can be detected by either amplitude or phase measurements along the path but further experience is necessary before it can be stated how accurately a boundary can be located and the constants on each side deduced.

Recommendations on the types of measuring apparatus and the accuracy to be expected from them, as sought in the third part of the question, must await a satisfactory answer to the first part, although data on the accuracy of all methods in use should be collected in the meanwhile.

The fourth part deals with the variation of measured values with frequency. There are two aspects of this point; the variation of the constants of homogeneous soil and the variation of the effective constants of inhomogeneous ground as the depth of penetration and spread of the waves changes with frequency. On both these aspects there is a certain amount of data, but further information, particularly on the relative importance of the two, is required.

The extent to which physical factors, e.g. vegetation and weather, affect the accuracy and interpretation of the measurements is the subject of the fifth part of the question. These factors can be regarded as having only an indirect effect on the ground constants. The weather, for example, may alter the constants because it causes a change in moisture content or temperature of the soil. Data on this subject is not easy to obtain because of the difficulty of isolating the effects of these factors and there is a need for carefully controlled experimental work.

Depth of penetration of waves into ground

Frequency	Depth δ (m)		
	$\sigma = 5 \times 10^{-11}$ e.m.u. $\epsilon = 81$	$\sigma = 1 \times 10^{-13}$ e.m.u. $\epsilon = 10$	$\sigma = 1 \times 10^{-14}$ e.m.u. $\epsilon = 5$
10 kc/s	2	50	150
100 kc/s	0.67	15	50
3 Mc/s	0.2	5	17
10 Mc/s		2	9

BIBLIOGRAPHY

Relating to § 3

1. SMITH-ROSE, R. L. The Electrical Properties of soil for Alternating Currents at Radio Frequencies. *Proc. Roy. Soc. A*, (1933), **140**, 359.
2. SMITH-ROSE, R. L. The Electrical Properties of Sea-water for Alternating Currents. *Proc. Roy. Soc. A*, (1933), **143**, 135.
3. SMITH-ROSE, R. L. Electrical Measurements on Soil with Alternating Currents. *J. I.E.E.*, (1934), **75**, 221.
4. WAIT, J. R. Propagation of Radio Waves over a Stratified Ground. *Geophysics*, (1953), **18**, 416.
5. FEINBERG, E. On the Propagation of Radio Waves along an Imperfect Surface. *J. of Phys. U.S.S.R.*, (1944), **8**, 317.
6. BARFIELD, R. H. The Attenuation of Wireless Waves over Land. *J. I.E.E.*, (1928), **66**, 204.
7. BARFIELD, R. H. and MUNROE, G. H. The Attenuation of Wireless Waves over Towns. *J.I.E.E.*, (1929), **67**, 253.

Relating to § 4

8. FELDMAN, C. B. The Optical Behaviour of the Ground for Short Radio Waves. *Proc. I.R.E.*, (1933), **21**, 764.
9. GISH, O. H. and ROONEY, W. J. Measurements of Resistivity of Large Masses of Undisturbed Earth. *Ter. Magn. and Atmos. Elect.*, (1925), **30**, 161.
10. WHITEHEAD, S. and RADLEY, W. G. Experiments relating to the Distribution of Alternating Electric Currents in the Earth and the Measurement of the Resistivity of the Earth. *Proc. Phys. Soc.* (1935), **47**, 589.
11. WAIT, J. R. and WAHLER, A. M. On the Measurement of Ground Conductivity at V.L.F. *N.B.S. Report No. 5037*.
12. SMITH-ROSE, R. L. and BARFIELD, R. H. On the Determination of the Directions of the Forces in Wireless Waves at the Earth's Surface. *Proc. Roy. Soc. A*, (1925), **107**, 587.
13. BARFIELD, R. H. *Some Measurements of the Electrical Constants of the Ground at Short Wave lengths by the Wave-Tilt Method*.
14. GILL, E. W. B. A Simple Method of Measuring Electrical Earth Constants. *Proc. I.E.E.*, (1949), **96**, 141.
15. GALLIGIONI, G. Ground Conductivity Measurements in Italy. *Alta Frequenza*, (1951), **20**, 119.
16. Effective Radio Ground-Conductivity Measurements in the United States. *N.B.S. Circular 546*, (1954).
17. VICE, R. W. A Survey of Ground Wave Propagation Conditions in South Africa. *Trans. S.A.I.E.E.*, (1954), **45**, 139.
18. NORTON, K. A. The Propagation of Radio Waves over the Surface of the earth and in the Upper Atmosphere. *Proc. I.R.E.*, (1936), **24**, 1367.
19. PRESSEY, B. G., ASHWELL, G. E. and FOWLER, C. S. The Measurement of the Phase Velocity of Ground-Wave Propagation at Low Frequencies over a Land Path. *Proc. I.E.E.*, (1953), **100**, Pt. III, 73.
20. MCPETRIE, J. S. A Determination of the Electrical Constants of the Earth's Surface at Wave lengths of 1.5 and 0.46 metres. *Proc. Phys. Soc.*, (1934), **46**, 637.

21. MCPETRIE, J. S. and SAXTON, J. A. Determination of the Electrical Properties of Soil at a Wavelength of 5 metres (Frequency 60 Mc/s). *J. I.E.E.*, (1943), **90**, Pt. III, 33.
22. GROSSKOPF, J. Über das Zennecksche Drehfeld im Bodenwellenfeld eines Senders (On Zenneck's rotating field in ground wave field of a transmitter). *Hochfrequenztechn. u. Elektroakustik*. (HFT), **59** (1942), 72.
23. GROSSKOPF, J. and VOGT, K. Über die Messung der Bodenleitfähigkeit (On the measurement of ground conductivity). *Telegr. Fernspr. Rf. u. Fernseh-Technik* (TFT), **29** (1940), 164.
24. GROSSKOPF, J. and VOGT, K. Zur Messung der Bodenleitfähigkeit (On the measurement of ground conductivity). *TFT*, **31** (1942), 22.
25. GROSSKOPF, J. and VOGT, K. Der Zusammenhang zwischen der effektiven Bodenleitfähigkeit und der Ausbreitungsdämpfung (The relation between the effective conductivity of the ground and propagation attenuation). *HFT*, **62** (1943), 14.
26. GROSSKOPF, J. Über Bodenleitfähigkeitsmessungen in Schleswig-Holstein (Measurements of ground conductivity in Schleswig-Holstein). *Fernmeldetechn. Zeitschrift*, **2** (1949), 211.
27. GROSSKOPF, J. Zur Ausbreitung von Mittelwellen über inhomogenes Gelände (On the propagation of medium waves over non-homogeneous terrains). *Fernmeldetechn. Zeitschrift* (FTZ), **3** (1950), 118.
28. GROSSKOPF, J. and VOGT, K. Ausbreitungsmessungen über inhomogenem Boden (Measurements of propagation over non-homogeneous terrains). *HFT*, **60** (1942), 97.
29. GROSSKOPF, J. Die Ausbreitung elektromagnetischer Wellen über inhomogenem Boden (The propagation of electro-magnetic waves over non-homogeneous terrains). *HFT*, **62** (1953), 103.
30. GROSSKOPF, J. and VOGT, K. Der Einfluss von Bodeninhomogenitäten auf die Funkbeschildung (The effect of ground heterogeneity in radiodirection-finding errors and its correction to zero). *Nachrichtentechn. Zeitschrift* (NTZ), **9** (1956), 349.
31. GROSSKOPF, J. and VOGT, K. Zur Höhenabhängigkeit des Zenneckschen Drehfeldes (On the dependence of Zenneck's rotating field on height frequency). *HFT*, **62** (1943), 172.
32. GROSSKOPF, J. Das Strahlungsfeld eines vertikalen Dipolenders übergeschichtetem Boden (The radiation field of a vertical-dipole transmitter on stratified soil). *HFT*, **60** (1942), 136.
33. GROSSKOPF, J. and VOGT, K. Die Messung der elektrischen Leitfähigkeit bei geschichtetem Boden (The measurement of electrical conductivity on stratified soil). *HFT*, **58** (1941), 52.
34. KASHIROVSKI. The propagation of radio waves and conductivity. *Radio Journal of U.S.S.R.*, (July, 1958) (in Russian). *National Bureau of Standards translation Tl-60*, (June 1959) (in English).

REPORT No. 140 *

GROUND-WAVE PROPAGATION OVER IRREGULAR TERRAIN

(Study Programme 89 (V))

(Geneva, 1951 — London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

The technical aspects of the problem of ground-wave propagation over irregular terrain may be usefully considered under two categories:

1. **Propagation between two specified points with an arbitrary intervening distance and heights above the ground, with an arbitrary intervening terrain profile, and through an arbitrary atmosphere.**

We will see that, in addition to being a direct solution of the point-to-point communication problem, the adequate treatment of this problem also provides indirectly the solution of most problems of interest to the C.C.I.R. As a consequence, most of the references attached to this report will deal with this problem.

2. **The statistical description of the fields expected from a broadcasting station at various locations along a circular arc at a given distance.**

As a practical matter, the atmosphere, as well as the characteristics of the ground, will vary with time, so that the ground-wave fields may also be expected to vary with time. As a consequence, problem (1) above also involves the statistical description of the fields. It is convenient for most engineering applications to consider simply the cumulative distribution of the received fields with time, i.e., to indicate the fields exceeded for various percentages of time on the specified point-to-point propagation path.

In problem (2) the statistical description of the ground-wave fields involves both time and receiving location as variables and, in practice, the shape, as well as the median, of the cumulative distributions with time will vary with location even with the distance fixed.

As soon as a satisfactory solution has been obtained of problem (1) as described above, then it can be considered that problem (2) is also solved since one can use statistical sampling methods to determine the separate cumulative distributions with time at a large number of locations along an arc at a constant distance from a broadcasting station. Each of these locations will correspond to a different profile of the terrain. It should be noted that cumulative distributions of the fields need not be determined at closely spaced locations along the arc since this will result in a redundancy of information by virtue of the correlation of the fields at closely spaced locations.

The statistical cumulative distributions of fields with time and location as described above may be predicted theoretically or measured. When resort is made to the use of measurements in the case of problem (2), one must face the difficulty that it is more or less impracticable to give anything more than a few distributions with location which will be representative of, for example, locations in gently rolling terrain, locations in small villages, locations in large cities, etc. For this reason, it is most desirable that suitable prediction formulae be developed so that they may be used to allow for the effects of the actual terrain encountered in particular situations.

* This report which replaces Reports Nos. 21 and 44, was adopted by correspondence without reservation (see page 9).

Irregularities in the terrain also have an influence on the scattered fields which will predominate over the ground wave fields at large distances beyond the radio horizon. This is considered to be a problem which should be considered in Study Group V although most of the above considerations are equally applicable to this problem as well.

When this field intensity information is used, for example by the I.F.R.B., in examining frequency allocations it is necessary to consider for point-to-point circuits (problem 1) the cumulative distribution with time of the ratio of the desired-to-undesired field intensity or, when a directional receiving antenna is used, the ratio of the desired-to-undesired available powers at the input to the receiver. This involves an appropriate combination of the separate cumulative distributions with time for the two propagation paths from the desired and the undesired transmitters. In making this combination it is sometimes important to consider the correlation in the variations of the desired and the undesired fields with time; for example, since the desired and undesired fields will usually change diurnally and seasonally in the same direction the cumulative distribution with time will extend over a somewhat smaller range than if this correlation did not exist. An interference free point-to-point service may be considered to exist when the desired-to-undesired ratio of available powers exceeds a predetermined value for a specified percentage of the time.

In the case of the determination of the interference to a broadcasting station from some other transmitter we may use the statistical sampling method and determine the cumulative distribution of the desired-to-undesired ratio of available powers at a large number of locations in the intended service area of the desired station. In this way we may determine the percentage of locations which will receive an interference free service.

It should be noted that the above method of analysis automatically makes the appropriate allowance for the fact that locations which are undesirable for reception of the desired signal are often also subject to a weak interfering signal.

The above discussion is intended to motivate the study by the C.C.I.R. of the effects on the ground wave of irregularities in the terrain. It appears that a satisfactory solution of any frequency allocation problem may be obtained when it is possible to determine the cumulative distribution with time of the desired-to-undesired field intensity ratio corresponding to the two irregular terrain paths between the receiving location to the desired and the undesired transmitters. At distances where the ground wave field may be an important component of the desired or undesired signal these scattered fields must be combined appropriately with the ground wave.

BIBLIOGRAPHY

1. KÜHN, U. Ausbreitungsuntersuchungen über unterschiedlichen Gelände in den Frequenzbändern I, II und III. *Technische Mitteilungen B.R.F. (D.D.R.)*, (February and May, 1958).
2. FURUTSU, K. Wave Propagation Over an Irregular Terrain, I, II and III. *Journal of Radio Research Laboratories*. Vol. 4, 16, 1957, Vol. 4, 18, (1957) and Vol. 6, 23, (1959).
3. FINE, H. UHF Propagation Within Line of Sight. *F.C.C. Report T.R.R. 2.4.12*.
4. SAXTON, J. A. Basic Ground-Wave Propagation Characteristics in the Frequency Band 50-800 Mc/s. *Proc. I.E.E.*, (1954), Vol. 101, Part III, 211.
5. SAXTON, J. A. and HARDEN, B. N. Ground Wave Field Strength Surveys at 100 and 600 Mc/s. *Proc. I.E.E.*, Vol. 101, Part III, 215, (1954).
6. KIRKE, H. L., ROWDEN, R. A. and ROSS, G. I. A VHF Field-Strength Survey on 90 Mc/s. *Proc. I.E.E.*, Vol. 98, Part III, 343, (1951).
7. *Report of Television Allocations Study Organisation to the Federal Communications Commission*, (1959).
8. NORTON, K. A., RICE, P. L. and VOGLER, L. E. Use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain. *Proc. I.R.E.*, Vol. 43, 1488, (1955).

9. NORTON, K. A. System Loss in Radio Wave Propagation. *National Bureau of Standards Journal of Research*, **63 D**, 53-73, July, (1959).
10. RICE, P. L., LONGLEY, A. G. and NORTON, K. A. Prediction of the cumulative distribution with time of ground wave and tropospheric wave transmission loss. *National Bureau of Standards, Technical Note No. 15*, (July 1959), Office of Technical Services U.S. Department of Commerce, Washington 25, D.C.
11. *Technische Berichte des Fernmeldetechnischen Zentralamtes Darmstadt* (Several papers are available which will be supplied on request).
12. *Hausmitteilungen des Norddeutschen Rundfunks* (Several papers are available which will be supplied on request).
13. Investigation of beyond the horizon propagation at 3000 Mc/s. *Doc. No. 182 (Sweden) of Los Angeles*, 1959.
14. Results of experimental study of UHF propagation over long distance paths across mountains. *Doc. No. 132 (U.S.S.R.) of Los Angeles*, 1959.
15. Theory of radio wave propagation over inhomogeneous earth, including diffraction by hills or mountains. *Doc. No. 53 (Japan) of Los Angeles*, 1959.

REPORT No. 141 *

GROUND-WAVE PROPAGATION OVER INHOMOGENEOUS EARTH

(Study Programme No. 135 (V))

(Warsaw, 1956 — Los Angeles, 1959)

The modifications introduced at Warsaw into the Study Programme reflected the considerable advances made between the London and Warsaw Assemblies. The progress made since the Warsaw Assembly has been equally marked and suggests further modifications to the Study Programme. This progress has been especially in the direction of generalizing the conditions under which it is possible to handle the rigorous mathematical analysis and to reduce it to a form of practical use to the engineer.

Because of the great complexity of the problem, various idealizations have been introduced in the theoretical analysis, for instance that the transmission path consists of well-defined homogeneous sections or that any stratification of the ground is parallel to the surface of the earth which is assumed to be smooth. Study is now being directed to the extension of the analysis to general cases more usually found in practical conditions. In view of the widening of the scope of the study, it is better to replace the term "mixed path" so far used, with its implied limitation to well-defined sections, by "inhomogeneous earth".

Even in the analysis of idealized cases certain mathematical approximations have to be made, but these are in general admissible except possibly in considering the field in the vicinity of a marked inhomogeneity. In this connection, an interesting investigation by Wait (A. 12) of the field in the immediate vicinity of the boundary between two sections of a path may be mentioned, where a more accurate analytical procedure has been adopted. His assumption that the surface impedances of the two sections are constant even up to the boundary is, however, an approximation that is not fully justified, at least without further examination.

* This Report which replaces Report No. 47, was adopted unanimously.

The problem of providing the engineer with graphical presentations enabling him to solve certain cases of propagation over well-defined sections or which allow him to make approximate computations of coastal refraction, has been considered in the following papers:

- by FEINBERG E. L. (C.1) where graphs are given referring to coastal refraction for wave-lengths of 300 and 600 metres;
- by WAIT J. R. (A.10) and WAIT J. R. and HOUSEHOLDER J. (A.11) where attenuation and phase data are presented in graphical form for two-section plane and spherical paths with various values of the conductivities;
- by FURUTSU K. (A. 6, 7; E.1) where graphical representations are given of the attenuation function for two-section plane paths, for certain three-section plane paths, and for many-section spherical paths consisting of a number of very long homogeneous sections;
- by GODZINSKI Z. (A.13) where curves are given which enable simple calculations to be made of attenuation and phase for two- and three-section plane paths and for many-section spherical paths, especially when the sections are alternately short and long.

In these papers the boundaries between the sections have been assumed sharp, whereas in practice they may be more or less gradual. However, the results of an investigation of the influence of a transition zone between sections have shown that in some special cases, at least at larger distances from the boundary, it is admissible to assume that the boundary is sharp instead of gradual, (C.1; A.16).

With regard to the analysis of the refraction caused by path inhomogeneities, it appears that it may be extended in the future to discuss the possibility of changes in wave polarization in the vicinity of inhomogeneities and its influence on errors in radio direction finding (A.9). On the other hand, the work carried out in the United Kingdom (A.17) suggests that in most practical cases large random errors are predominant and that it is impracticable to use experimental measurements to check the theoretical estimates of ground-wave deviation at a coast-line. It is similarly difficult to check the theory of wave propagation parallel to a boundary by field-strength measurements made along a coast line.

The discussion of the effect of horizontal stratification of the ground (B1, B4, B5, B6 and B7) has shown that it is possible to introduce effective earth constants which determine both the attenuation of the wave and the shape of its ellipse of polarization. When the inhomogeneity of the ground is of a more complicated nature, the connection between the effective earth constants and the shape of the polarization ellipse is much more complicated and that is a factor that is of importance in the measurements of the electrical parameters of the ground.

The changes of the electrical constants of the ground have an influence on the amplitude, phase, polarization ellipse and the height-gain factor relative to the ground-wave. None of these characteristics depends, however, in a simple manner on the local values of the earth constants. This problem is important in connection with the possibility of geological prospecting by radio methods and it is due for fuller investigation in the future.

It may be noted that, in an increasing number of theoretical investigations using approximate boundary conditions, use is being made of the concept of surface impedance. It is thought that this trend may be useful to practical engineers who are familiar with this concept in other fields. There exists, in fact, a close analogy between inhomogeneous transmission lines and horizontally stratified ground which may prove helpful when calculating effective earth constants, (B4, B5, B6, B7 and B10).

Because of the labouriousness of the theoretical methods, the most widely accepted of the semi-empirical methods, (F3, F4, F5 and F6) namely Millington's method and the equivalent numerical distance method (equivalent conductivity method) (F1, F2), have been compared with theory (F.8). Millington's method has been found to give good agreement with theory and it is believed that it may be used for most practical purposes. The agreement is closer for amplitude than for phase, but even in the case of phase changes, it gives results that are within the limits of practical measurements, bearing in mind the difficulties mentioned above.

The methods of equivalent numerical distance or equivalent conductivity have the advantages of simplicity [where many computations have to be made, but they can sometimes give rise to large errors. It is therefore necessary when using this method to take great care to remain within the domain of its limited application, making, if need be, controlled checks by other methods at a number of points within the range in which it is wished to apply it.

In the past it has been assumed that the ground, though inhomogeneous, is smooth, either plane or spherical. It is now being recognized that the fact that the ground may also be irregular may affect the study of the inhomogeneities. The analysis of such a general problem is, however, extremely difficult (C1 to C7). Great value may, therefore, be attributed to the investigations of Furutsu (C2 and C3) who, in addition to showing the close analogy between the analysis for propagation over inhomogeneous earth and over a surface with small undulations, has succeeded in combining both aspects of ground-wave propagation in the same analysis. He has given formulas and curves for some special cases which may be of great practical value and has opened the way to a more general study including at the same time both surface irregularities and inhomogeneities of the ground.

BIBLIOGRAPHY

A. Theoretical Investigations of Propagation over Inhomogeneous Earth

1. *Investigations of Propagation of Radio Waves*, ed. by B. A. Vvedensky, a symposium, Publ. by Ac. Sci. U.S.S.R., Moscow-Leningrad, (1948) (in Russian).
2. FEINBERG, E. L. *Theory of Ground-Wave Propagation over Earth Surface* and with ALPERT, J. L. and GINZBURG, V. L.: *Radio Wave Propagation*. GITTL, Moscow, (1953), Part I, Chapt. IX, 184 (in Russian).
3. MONTEATH, G. D. Application of the Compensation Theorem to Certain Radiation and Propagation Problems. *Proc. I.E.E.*, Part IV, (1951), **98**, 23.
4. CLEMMOW, P. C. Radio Propagation over a Flat Earth across a Boundary separating two Different Media. *Phil. Trans. Roy. Soc. A*, (1953), **246**, 1.
5. BREMMER, H. The Extension of Sommerfeld's Formula for the Propagation of Radio Waves over a Flat Earth to Different Conductivities of the Soil. *Physica*, (1954), **20**, 441.
6. FURUTSU, K. Propagation of Electro-Magnetic Waves over a Flat Earth across a Boundary Separating Different Media and Coastal Refraction. *J. Radio Res. Lab. (Tokyo)*, (1955), **2**, 1.
7. FURUTSU, K. Propagation of Electro-Magnetic Waves over a flat Earth across Two Boundaries separating Three Different Media. *Ibid.*, (1955), **2**, 239.
8. FURUTSU, K. Propagation of Electro-Magnetic Waves over the Spherical Earth across Boundaries Separating Different Earth Media. *Ibid.*, (1955), **2**, 345.
9. SENIOR, T. B. A. Radio Propagation over a Discontinuity in the Earth's Electrical Properties — I, and II. Coastal Refraction. *Proc. I.E.E.*, Part C, (1957), **104**, 43, 139.
10. WAIT, J. R. Mixed Path Ground Wave Propagation: 1. Short Distance. *J. Res. NBS*, (1956), **57**, 1.
11. WAIT, J. R. and HOUSEHOLDER, J. Mixed-path Ground-Wave Propagation: 2. Larger Distances. *Ibid.*, (1957), **59**, 19.
12. WAIT, J. R. Amplitude and Phase of the Low-Frequency Ground Wave Near a Coastline. *Ibid.*, (1957), **58**, 237.
13. GODZINSKI, Z. The Use of Equivalent Secondary Sources in Theory of Ground-Wave Propagation over an Inhomogeneous Earth. *Proc. I.E.E.*, Monograph No. 299 R, April 1958, republished in *Proc. I.E.E.*, Part C, (1958), **105**, 448.
14. KALININ, Yu. K. and FEINBERG, E. L. Ground-Wave Propagation over Inhomogeneous Spherical Earth's Surface. *Radiotechn. and Elektron.*, (1958), **3**, 1122 (in Russian).
15. KALININ, Yu. K. Diffraction of Radio Waves over Inhomogeneous Spherical Earth's Surface. *Ibid.*, (1958), **3**, 1274 (in Russian).
16. HOUTSMULLER, J. Ground-Wave Propagation — Mixed Path. *Tijdschr. Nederl. Radiogen.* (to be published).
17. Ground-Wave Propagation over Mixed Paths. The Deviation of Ground Waves at a Coast-Line. *C.C.I.R. Doc. IV/2 (United Kingdom) of Geneva*, 1958.

B. Theoretical Investigation of Propagation over Stratified Ground

1. GROSSKOPF, J. Das Strahlungsfeld eines vertikalen Dipolenders über geschichtetem Boden. *Hochfr. und El. Ak.*, (1942), **60**, 136.
2. BREKHOVSKIKH, L. M. The Field of a Point Source in a Stratified Medium. *Bull. Ac. Sci. U.S.S.R., Phys. ser.*, (1949), **13**, 505 (in Russian).
3. WAIT, J. R. The Fields of a Line Source of Current over a Stratified Conductor. *Appl. Sci. Res., Sect. B*, (1953), **3**, 279.
4. WAIT, J. R. Radiation from a Vertical Electric Dipole over a Stratified Ground. *Trans. I.R.E.*, (1953), Vol. AP-1, 9.
5. WAIT, J. R. and FRASER, W. C. G. Radiation from a Vertical Dipole over a Stratified Ground (Part II). *Ibid.*, (1954), Vol. AP-3, 144.
6. WAIT, J. R. Theory of Electromagnetic Surface Waves over Geological Conductors. *Geofisica Pura Appl.*, (1954), **28**, 47.
7. WAIT, J. R. Radiation from a Vertical Antenna over a Curved Stratified Ground. *J. Res. NBS*, (1956), **56**, 237.
8. PAVINSKY, P. P. and KOZULIN, Yu. N. The Field of a Vertical Magnetic Dipole over a Two-Layer Medium. (*Geofisika*, publ. by Leningrad Univ., 1956), 134 (in Russian).
9. KOZULIN, Yu. N. The Field of a Vertical Magnetic Dipole over a Two-Layer Medium Computation of Functions T/p , z/p . *Ibid.*, 158 (in Russian).
10. BREKHOVSKIKH, L. M. *Waves in Stratified Media* (publ. by Ac. Sci. U.S.S.R., Moscow, 1957) (in Russian).

C. Theoretical Investigations of Propagation over Irregular and Inhomogeneous Earth

1. FEINBERG, E. L. Propagation of Radio Waves over Real Surface. *Reference A. 1*, 97 (in Russian).
2. FURUTSU, K. On the Multiple Diffraction of Electro-Magnetic Waves by Spherical Mountains. *J. Radio Res. Lab.* (Tokyo), (1956), **3**, 331.
3. FURUTSU, K. Wave Propagation over an Irregular Terrain, (I), (II), (III). *Ibid.*, (1957), **4**, 135, 349 and (1959), **6**, 71.
4. WAIT, J. R. On the Theory of Propagation of Electromagnetic Waves along a Curved Surface. *Can. J. Phys.*, (1958), **36**, 9.
5. KALININ, Yu. K. Perturbation of the Field of a Plane Radio Wave by Inhomogeneity of Earth's Surface. *Radiotechn. and Elektron.*, (1958), **3**, 557 (in Russian).
6. BREMMER, H. Application of Operational Calculus to Ground-Wave Propagation, in particular for Long Waves. *Proc. I.R.E.* (to be published).
7. BREMMER, H. *Encyclopedia of Physics*. (S. Flüge), Springer, Berlin, (1958), Vol. 16, Sect. 68-73, 531.

D. Theoretical Investigations of Pulse Propagation over Inhomogeneous Earth

1. WAIT, J. R. Propagation of pulse across a Coast Line. *Proc. I.R.E.*, 1957, **45**, 1550.
2. LOWNDES, J. S. A Transient Magnetic Dipole Source above a Two-Layer Earth. *Quart. J. Mech. Appl. Math.*, 1957, **10**, 79.

E. Papers with Geographical Presentations Facilitating Practical Computations

1. FURUTSU, K. and KOIMA, S. The Calculation of Field Strength over Mixed Paths on a Spherical Earth. *J. Radio Res. Lab.* (Tokyo), 1956, **3**, 391.
2. See also papers: A. 6, 7, 10, 11, 13; C. 1.
3. The Need for a Number of Standard Two-path Ground Wave Field Intensity Decoy and Recovery Curves. *C.C.I.R., Doc. No. 18 (New Zealand) of Los Angeles, 1959*.

F. Semi-Empirical Methods

1. GROSSKOPF, J. and VOGT, K. Der Zusammenhang zwischen der effektiven Bodenleitfähigkeit und der Ausbreitungsdämpfung. *Hochfr. und El. Ak.*, (1943), **62**, 14.



2. GROSSKOPF, J. Zur Ausbreitung von Mittelwellen über inhomogenes Gelände. *Fernmeldetechn. Zs.*, (1950), **3**, 118.
3. MILLINGTON, G. Ground Wave Propagation over an Inhomogeneous Smooth Earth. *Proc. I.E.E.*, Part III, (1949), **96**, 53.
4. MILLINGTON, G. and ISTD, G. A. Ground Wave Propagation over an Inhomogeneous Smooth Earth. Part 2. Experimental Evidence and Practical Implications. *Ibid.*, (1950), **97**, 209.
5. KIRKE, H. L. Calculation of Ground-Wave Field Strength over a Composite Land and Sea Path. *Proc., I.R.E.*, (1949), **37**, 489.
6. PRESSEY, B. G., ASHWELL, G. E. and FOWLER, C. S. The Measurement of the Phase Velocity of Ground-Wave Propagation at Low Frequencies over a Land Path. *Proc. I.E.E.*, Part III, (1953), **100**, 73.
7. SUDA, K. Estimation of Medium-Wave Field Strength over Mixed Paths. *C.C.I.R., Doc. Nos. 140 and 232 (Japan)*, of London, 1953.
8. GODZINSKI, Z. A Comparison of Millington's Method and the Equivalent Numerical Distance Method with the Theory of Ground-Wave Propagation over an Inhomogeneous Earth. *Proc. I.E.E.*, Part C, Monograph No. 318 R, (Dec. 1958) (to be published later in 106 C).
9. LATMIRAL, G. Radiation of Horizontal Antenna and Measurement of Electrical Constants of the Earth. *Alta Frequenza*, **7**, (1938), 509.
10. SACCO, L. and BARZILAI, G. On the Measurement of Electrical Constants of the Earth at Very High Frequencies. *Rassegna delle Poste e delle Telecomunicazioni*, (1940), **9**, 597.
11. ARGIROVIĆ, M:
 - (a) Propagation of electromagnetic waves over an inhomogeneous earth. *Elektrotehnički Vjesnik*, **8-9**, 225-231 (1951).
 - (b) Methode générale de calcul des conductivités du sol hétérogène. *Ann. Telecomm.*, **8**, 212-224 (1953).
 - (c) Variations de la constante de phase de l'onde de sol. *Onde Electrique*, **35**, 687-691 (1955).
 - (d) Ground-wave propagation over mixed paths. *Doc. No. 221 (Yugoslavia) of Warsaw*, 1956.

REPORT No. 142 *

**MEASUREMENT OF FIELD STRENGTH FOR VHF (METRIC)
AND UHF (DECIMETRIC) BROADCAST SERVICES, INCLUDING TELEVISION**

(Question No. 138 (V))

(Los Angeles, 1959)

1. Description of coverage.

For the purpose of frequency assignment, the description of coverage for VHF (metric) and UHF (decimetric) broadcast services such as television, broadcasting, frequency modulation broadcasting, etc., should be in terms of the extent to which service is provided to potential viewers or listeners. The service may be classified in accordance with the quality of the signal at an individual location. For the purpose of assigning stations it is probably necessary to consider only one quality of service; however, it may be useful for other purposes to define more than one quality.

Several methods have been proposed for describing the service coverage of broadcast stations in the VHF (metric) and UHF (decimetric) bands. The present Report discusses a method, currently used in the United States.

* This Report was adopted by correspondence without reservation (see page 9).

An acceptable method for describing broadcast service should meet the following general criteria [1]:

1.1 It should show the location and extent of all areas provided with a given quality of service.

1.2 It should take into account significant time variations.

1.3 The method of specifying service should be sufficiently fine-grained to be capable of showing the amount (area or population) and location of service in distinct areas and directions from the transmitter.

1.4 It should be capable of showing the effect of interference from one or more stations in terms of the amount and location of service lost.

1.5 It should be capable of showing two or more qualities of service.

1.6 It should be possible to predict the service area by means of a reasonable number of measurements and/or calculations of field strength.

1.7 It should lend itself to simple two-dimensional presentation.

After extensive studies on the various methods for describing VHF (metric) and UHF (decimetric) broadcast service, the *location probability* has been recommended [1, 2] as the best statistic for describing service. A brief description of the meaning of this statistic is in order for those not familiar with the term. Under steady state laboratory conditions, it has been possible to evaluate statistically the ratios of desired-signal to interference which are required to produce pictures or sound of a quality acceptable to different observers in the presence of various types of interference. The ratio accepted by some percentage of the observers, say 50% is chosen as the acceptance ratio for each type of interference. At any specific location, the desired signal and/or the interference may vary with time, so that the term *time-availability* is used to indicate the percentage of time for which the acceptance ratio is exceeded. A particular quality of service corresponds to a specified acceptance ratio exceeded for a given percentage of time at an agreed standard receiving installation. The location probability is then defined as the probability of receiving this quality of service or better. Alternatively the location probability may be defined as the percentage of locations in a small area for which this quality of service or better is expected. To minimize computations, the single value of 90% time availability may be adopted as the satisfactory level. This figure might be changed as found desirable, or several levels and standard receiving installations might be adopted to show different qualities of service.

Location probability describes in a satisfactory manner the location and amount of the service available from the point of view of the station assignment and allocation planner, the operating authority and the viewer or listener. It is believed that this statistic is the most meaningful and practical for the description of TV and FM broadcast service and easily meets all the above criteria. Location probability is preferable to the signal-to-interference ratio or the desired signal level as a service index because it provides a comparable measure of the quality of service which is independent of frequency, distance, etc. Although the signal-to-interference ratio might be more easily comprehended, it has the great disadvantage of requiring different numbers at different frequencies and distances to describe the same quality of service. The desired signal level is an unsatisfactory index in that it varies with frequency and cannot take into account interference other than receiver noise. However, when the interference is receiver noise then contours of constant location probability will also be contours of constant field strength. Procedures for the computation of location probability are relatively simple and rapid [2, 3].

Two illustrations of the presentation of service by the use of location probability are given in Figs. 1 and 2. The solid curves represent contours of constant service along which the location probability of a given quality of service is constant for a standard installation. In the U.S.A., the Federal Communications Commission identifies certain of these contours of equal service with particular grades of service. The numbers indicate the average location probability between

the bordering iso-service contours. For example the areas marked as having an average location probability of 0.70 are bordered by the 0.60 and 0.80 iso-service contours. The iso-service contours could have been labelled rather than the enclosed areas. Fig. 1 shows a great amount of detail, possibly more than could be shown normally with a practical amount of data. However, such detail might be desired for specific sections of a station service area, depending upon the particular problem at hand. Fig. 2 shows what a service map might look like in a more typical case, where the great amount of data for a more detailed map like Fig. 1 is not available.

It is well known that under practical operating conditions many people will use an installation just good enough to provide a satisfactory service, but will go to extremes in order to get the service. Thus, in a strong signal area many people will use indoor antennas, whereas in weak signal areas many will employ extremely good installations. Consequently, the number of people receiving a satisfactory signal may well be different than that computed from location probabilities based on a standard receiving installation. However, to provide an objective description of available service, it is desirable to refer always to a fixed quality of service, received on a standard installation. The adoption of a standard receiving installation also makes possible the computation of the combined effects of multiple sources of interference.

Besides meeting all the required criteria, this portrayal of service has several other advantages. The effective service area or the population served by an individual station may be computed by summing the products of the location probability multiplied by the area or the population respectively to which this probability applies [2, 3].

This method of portrayal is also convenient for estimating the interference effects of existing, new or proposed stations in neighbouring areas. Thus the overall location probability for service in the presence of a number of interfering services is approximately the product of the individual location probabilities for service of the desired station in the presence of each source of interference acting alone [2]. This approximation is fairly good when the resultant overall location probability is 50% or better and improves as the resultant service increases. More accurate methods for computing the effects of multiple interference are also available [2, 4].

2. Method of measurement.

Field strength measurements of metric and decimetric wave broadcasting stations are made to meet the following objectives:

- 2.1 To provide a basis for assessing the extent of service of any given quality.
- 2.2 To check the directional pattern and power radiated from a transmitting antenna.
- 2.3 To provide data with a view to increasing general knowledge on propagation conditions in the bands concerned.
In making measurements the following conditions should be fulfilled:
- 2.4 Measurements should be readily reproducible so that they can be checked subsequently, if required.
- 2.5 The procedure should provide the required information in an efficient manner.
- 2.6 The method should not be impractical, hazardous nor too expensive.

Various measurement methods currently in use fulfill the foregoing criteria with varying degrees of success. A description of an acceptable method and the advantages it provides will be given in the following.

It is certainly easier to make the measurements if the wave collector is about 3 or 4 metres above the ground, but a height of 10 metres more nearly corresponds to the height of the receiving antenna of a typical installation. After obtaining results for a height of 3 metres in relatively flat and open terrain, they can be suitably corrected for height, but height correction is difficult

in the case of very irregular terrain or built-up areas, more particularly at UHF. Therefore, 10 metres would seem to be the best height for the measurement antenna.

As a rule, it is not convenient to make measurements at a height of 10 metres over long lengths of road, near overhead wires, trees, etc.; but short runs (10 to 150 metres) or individual spot measurements can be made at this height. As will be described in more detail below, it is possible to use a systematic statistical sampling procedure for determining the locations at which these short runs or spot measurements should be made. The degree of accuracy in estimating the area or population provided with a given quality of service may also be determined. The short distance runs are made along a short section of road centred on the measurement point selected and the median value of the field measured on this run is referred to this location. As compared with spot measurements made at the given location the advantage of the short distance runs is that the median value which it gives is more readily reproducible. Spot measurements are more easily made and may also be used to obtain a distribution of the field with respect to time over the period involved.

Antennae suitably adapted to a communications receiver should be used and the transmission line should be shielded. An antenna with a gain of 6–10 db is proposed for bands III, IV and V, but the antenna for bands I and II will usually have a lower gain for practical reasons of the space required.

In the presentation of the results the exact position of the measuring points is plotted on a map and the median or spot field value at those points is shown. The following particulars are noted for each point in a separate report; local topography, height and type of vegetation, housing, obstacles, weather conditions, times of day and any other local features likely to affect the received field (if necessary, photographs from measuring sites can be provided). An indication should also be given of the median, maximum and minimum field strength values for each short mobile run or measurement group and of the direction from which the maximum signal arrives if other than the direction of the transmitter.

In order to assess the extent of service, the measurement procedure may be considered a sampling process in which the cumulative distribution of the sample represents an estimate of the variations within a given area of the actual fields. The choice of sampling locations should be free of bias and should represent typical operating installations as nearly as possible. An important factor affecting the choice of sampling locations is the tendency for successive measurements made adjacent to each other to be correlated among themselves, that is to be serially correlated. Measurements made with sufficient separation to eliminate serial correlation provide an efficient estimate of the variations of the fields. Studies indicate that significant serial correlation between successive measurements will be present at separations normal to the path of propagation up to one or two kilometres [3, 5 and 6]. Serial correlation will be present in radial measurements at even greater separations.

In order to arrive at an estimate of the cumulative distribution of field strength in an incremental area within the service area of the transmitter, a sample set of measurements should be obtained in such a way that the propagation characteristics are similar throughout the area of measurement. For example, systematic effects, such as large variations of field with distance, should be avoided. One way in which this can be accomplished is to confine each set of sample measurements to an annular ring-shaped area, or segment thereof, centred on the transmitter.

The measurement locations should be laid out on circles or circular arcs centred on the transmitter. The choice of radii for the circles will depend largely upon the location probabilities expected. Therefore, it is extremely helpful to make estimates in advance of the dependence upon distance of the location probabilities for the particular case in question. Fig. 3 shows a hypothetical example of this dependence based on a field strength versus distance relation for a television station operating in the 54 Mc/s to 88 Mc/s frequency band and assuming a log normal distribution with a standard deviation of 6 db to represent the dispersion of field strength values in the incremental areas. Studies of irregular-terrain propagation at these frequencies [2, 3, 5, 6 and 7] indicate that the logarithm of the field strength is approximately normally distributed. In this example, the location probabilities indicate the percentage of the areas at the distances indicated

that would be expected to have a field strength in excess of 57 db rel. to $1 \mu\text{V/m}$. Fig. 4 illustrates a possible distribution of locations for the measurements. It should be noted that the greatest concentration of points is proposed in this example at the distance for which the location probability is 0.5 in order to provide in the most efficient manner information about the total area served. The separations between adjacent measurements should be adequate to eliminate, or at least to minimize, the effects of serial correlation.

When the proposed measurement locations, determined in a manner similar to Fig. 4, are transposed to an actual map, it will be found that many of them lie in inaccessible areas. In such cases the measurement will probably be made nearby at a location which is accessible. The important point to consider in choosing alternate locations is to avoid introducing bias, such as might be the case, for example, if these alternate locations were unduly concentrated along highways.

It would be a relatively simple matter to include other observations along with the basic field-strength measurements. At a selected number of the locations time variations could be recorded over a reasonably long period of time. Also the effect of antenna height, antenna directivity, picture or sound quality, etc., could be observed. Additional measurements could be made in areas of special interest.

ANNEX

It is clear that if the entire area surrounding the transmitter, within which service to any degree is available, were to be divided up into small areas $a_1, a_2, a_3, a_4, \dots a_i \dots a_n$, having true location probabilities $p_1, p_2, p_3, p_4, \dots p_i, \dots p_n$, based on the choice of a specific quality of service, then the total service area for this quality can be expressed as

$$A = \sum_{i=1}^n p_i a_i$$

Estimates of p_i , denoted as P_i are the fractions of the total measurement points in each elemental area in which the given quality of service is obtained. The confidence in the final result [3] can be established from a consideration of the variance in the estimate of A

$$\sigma_A^2 = \sum_{i=1}^n a_i^2 \cdot \sigma_{P_i}^2$$

The variances $\sigma_{P_i}^2$ can be simply approximated, under the assumption that the estimates P_i are independent, as

$$s_{P_i}^2 = \frac{P_i (1 - P_i)}{N_i}$$

where N_i denotes the number of field-strength observations made in each area a_i . The above expressions point out an interesting fact. In order to keep the variance in the estimates P_i small, the greatest concentration of measurements should be made in the areas where the location probability is close to 0.5. The expression for $s_{P_i}^2$ is based on the assumption that the estimates P_i have binomial distributions. If use were made of the fairly well established log-normal distribution of field strengths the estimates of variance based on this latter assumption would, on the average, be slightly smaller than those indicated by the above formula.

In Fig. 4 a total of 507 measuring locations are distributed on radii as follows:

36 km, $P_i = 0.993$,	$N_i = 16$;
52 km, $P_i = 0.875$,	$N_i = 91$;
68 km, $P_i = 0.5$,	$N_i = 180$;
85 km, $P_i = 0.13$,	$N_i = 150$;
101 km, $P_i = 0.012$,	$N_i = 58$;
117 km, $P_i = 0.00036$,	$N_i = 12$.

In this example, if the values of P_i represent estimates of the location probabilities, the total area served is estimated to be 15,450 square kilometres, and the standard deviation about this estimate is found to be $\sigma_A = 431.5$ square kilometres. If more measurements were made the estimates of service area would not be much improved because of the correlation between the measurements

BIBLIOGRAPHY

1. Report to the Federal Communications Commission of Committee 5.3 of the Television Allocation Study Organisation (TASO); (March 1959).
2. Volumes I and II of the Report of the ad hoc Committee for the Evaluation of the Radio Propagation Factors concerning the TV and FM Broadcasting Services in the Frequency Range between 50 and 250 Mc/s. Federal Communications Commission, Mimeograph 36830, (May 1949); and Mimeograph 54382, (7 July 1950).
3. KIRBY, R. S. Measurement of Service Area for Television Broadcasting. *Trans. I.R.E., PGTS-7*, 23, (February 1957).
4. NORTON, K. A., STARAS, H. and BLUM, M. A Statistical Approach to the Problem of Multiple Radio Interference to FM and Television Service. *Trans. I.R.E., AP-1*, 43, (February 1952).
5. KIRBY, R. S. and CAPPS, F. M. Correlation in VHF Propagation Over Irregular Terrain. *Trans. I.R.E., AP-4*, 1, 72, (January 1956).
6. KIRBY, R. S., DOUGHERTY, H. T. and MCQUATE, P. L. VHF Propagation Measurements in the Rocky Mountain Region. *Trans. I.R.E., PGVC-6*, 13, (July 1956).
7. KUHN, U. Ausbreitungsuntersuchungen über unterschiedlichem Gelände in den Frequenzbändern I, II und III. *Technische Mitteilungen aus dem Betriebslaboratorium für Rundfunk und Fernsehen (BRF) (DDR)*, (February and May 1958). (Propagation Investigation of the Effect of Various Types of Terrain in Frequency Bands, I, II and III.)

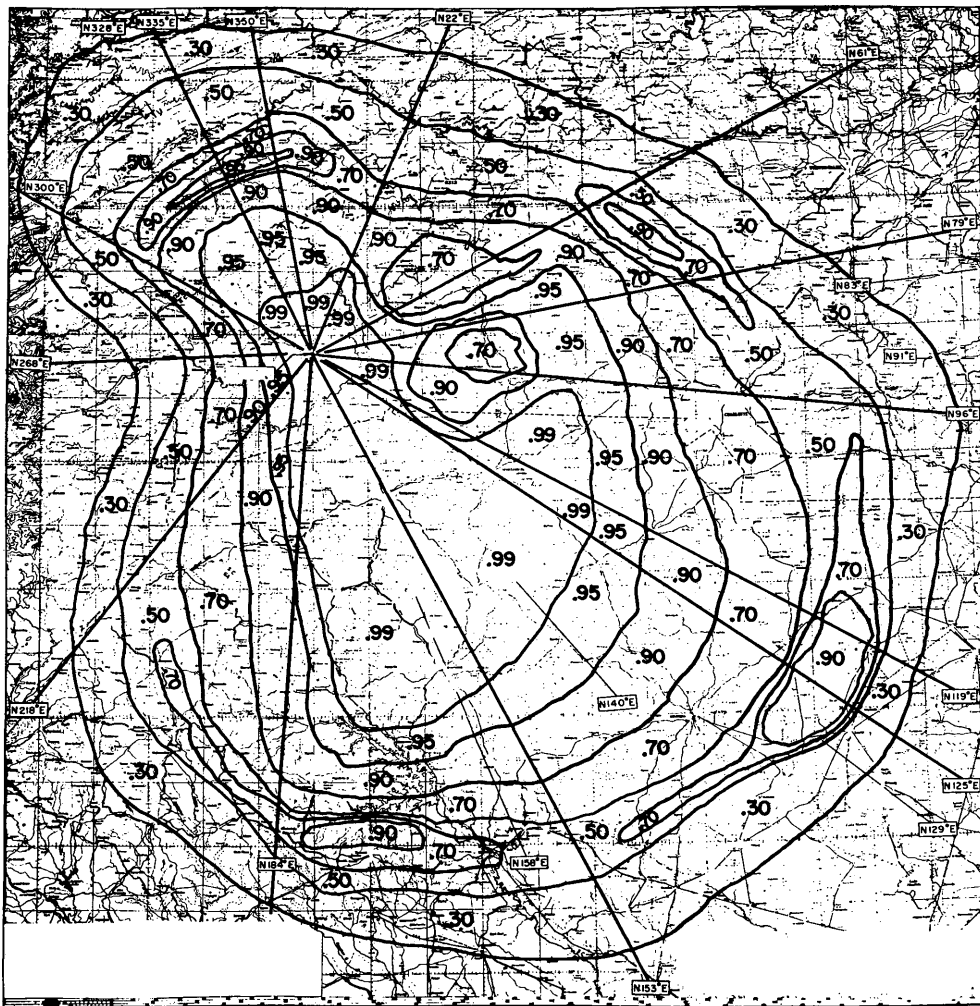


FIGURE 1

Service probability concept

(Numbers indicate probability of locations receiving acceptable service for at least 90% of the time)

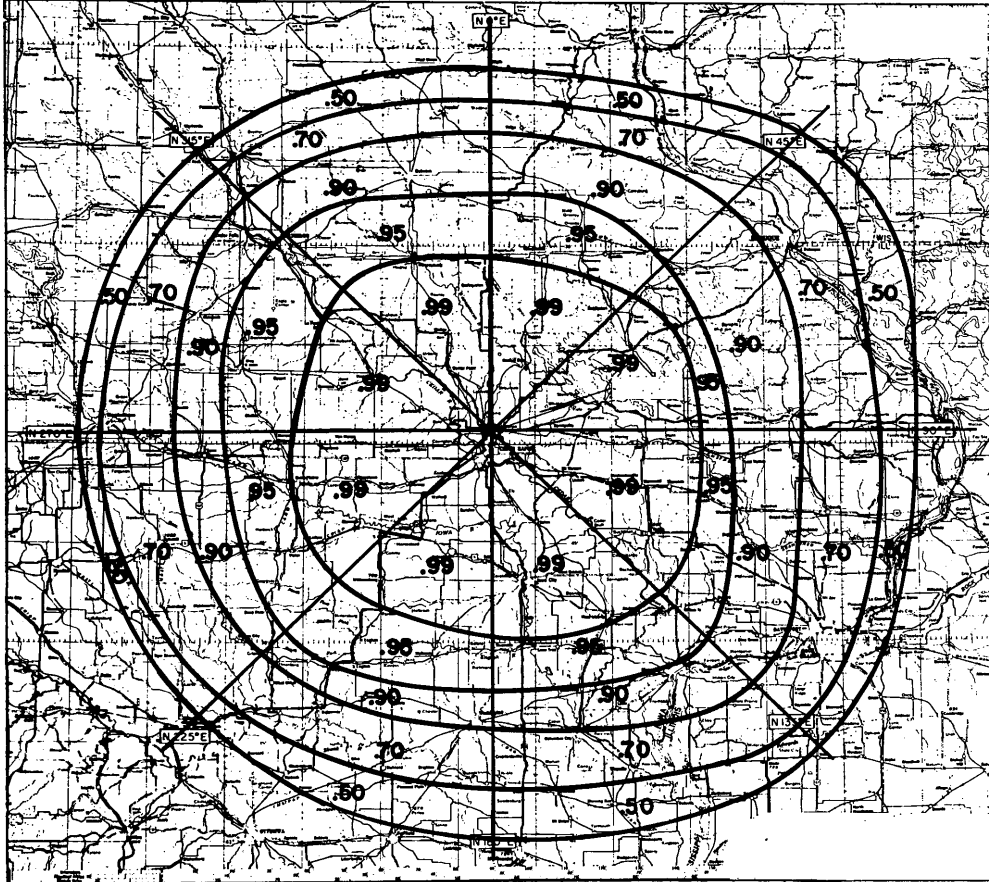


FIGURE 2

Service probability concept

(Numbers indicate probability of locations receiving acceptable service
for at least 90% of the time)

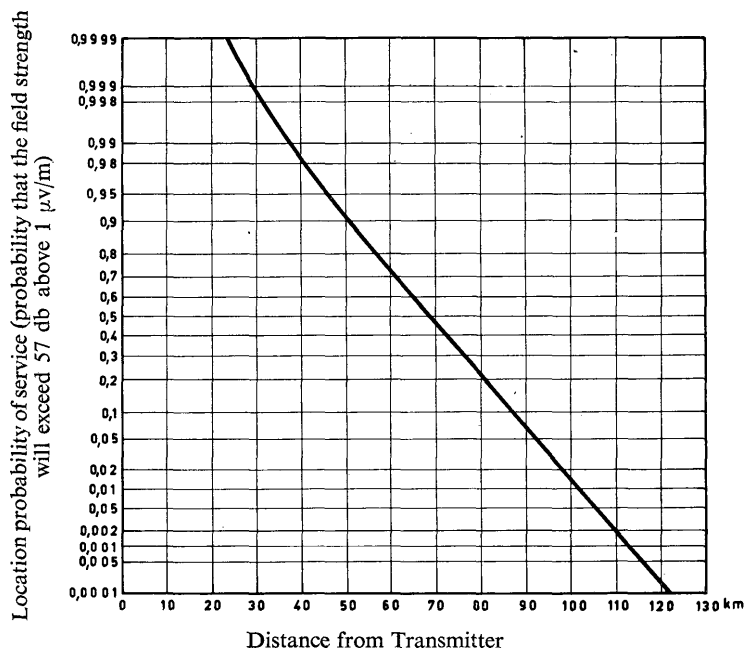


FIGURE 3

Variation of the location probability of service with distance from the transmitter. Based on typical propagation characteristics of a television station operating at 100 kW ERP in the 54—88 Mc/s band

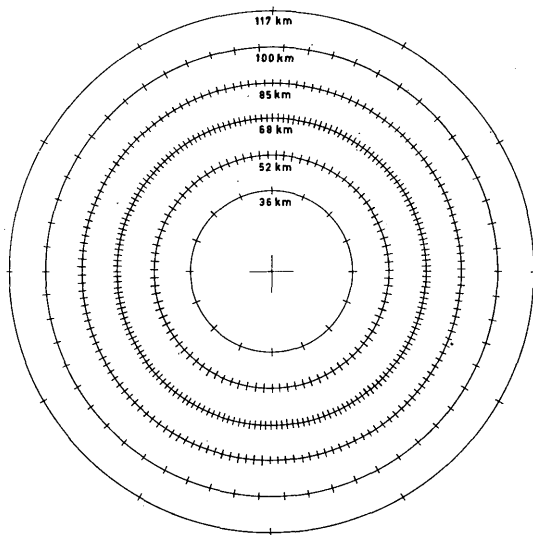


FIGURE 4

Possible scheme of measurements for a 100 kW station over average terrain (The transmitter is located at the centre of the diagram).

REPORT No. 143 *

PROPAGATION DATA REQUIRED FOR RADIO-RELAY SYSTEMS

(Question No. 185 (V))

(Los Angeles, 1959)

Information on this subject was received at Geneva, 1958 in Docs. V/5 (U.K), V/18 (Japan), V/22 (Federal German Republic), V/28 (France) and V/32 and V/33 (Italy).

Doc. V/18 (Japan) deals with the derivation of a semi-empirical formula for the prediction of the radio frequency dependence of the fading ranges. This formula is based upon the experience that the fading of radio field strengths may be described as composed of a slowly varying component and a rapidly varying component. This formula predicts fading ranges that are in good agreement with measured values on 200 and 1,000 Mc/s over distances from 45 to 150 km. Data submitted in Doc. 35 (Japan) of Los Angeles, is attached at the end of this Report.

Doc. V/28 (France) discusses the methods of presentation of statistical data for this question. The aim of this method is to sub-divide the observation intervals according to differing fading characteristics in order to facilitate the study of the physical causes of these fading characteristics.

Doc. V/5 (United Kingdom) summarizes experience obtained by measuring the radio path attenuation for each month of the year for the percentage levels specified by Question No. 185 (V) at a frequency of 42 Mc/s over a 360 km oversea path. Additional information is given for overland and oversea paths of 40 to 75 km length at a frequency of 4000 Mc/s.

Doc. V/22 (Federal German Republic) reports on the field variations over three propagation paths at frequencies of 2000, 4000 and 7000 Mc/s and path distances of 44 to 142 km.

Docs. V/32 and V/33 (Italy) contributed individual monthly variations of radio path attenuation for frequencies of 250, 500 and 1000 Mc/s over a 189 km path as well as similar measurements made over 238 km path at a frequency of 1000 Mc/s. Similar values are given for two radio paths of 370 and 385 km at a frequency of 238 Mc/s.

There is obviously insufficient information available as yet for a complete answer to the question and it should remain under study. However, it is felt that a summary of the data relating to Section 1 of the Question, which comprises the major part of the information given in the documents, would be of use to the designer of radio links. Accordingly, the following table has been prepared for the months of February, May, August and November. Reference should be made to the documents for data for other months.

It must be emphasised that the figures given in this report cannot be considered as more than a general guide and that it may be desirable in any practical case to make measurements over the path.

* This Report which replaces Report No. 53, was adopted by correspondence without reservation (see page 9).

TABLE 1

Country	Path length (km)	Frequency (Mc/s)	Month and year or number of months	Height (m)		Excess of path attenuation over free space loss for quoted percentage of time (db)										Re- marks
				Trans.	Rec.	99.9	99.0	90.0	50.0	10.0	1	0.5	0.1	0.01		
United Kingdom	360	42	November 1956 February 1956 May 1957 August 1957	590	260	33 45 8 12	37 46 9 13		57 60 37 35		75 79 68 67		79 81 74 75	81 82 75 76	n/s	
	40	4000	2 months of May	160	300	a	a		a		a		12	14	o/l	
	46	4000	4 months of Feb. 4 months of May 4 months of Aug.	350	160	a a a	a a a		a a a		a a a		14 a 12	18 14 14	o/l	
	56	4000	4 months of Feb. 4 months of May 5 months of Aug. 5 months of Nov.	320	270	a a a a	a a a a		a a a a		a a a a		a 16 18 12	13 33 23 14	o/l	
	64	4000	1 month of Feb. 1 month of May 1 month of Aug.	200	300	a a a	a a a		a a a		14 11 a		19 29 13	22 37 19	o/l	
	64	4000	1 month of Nov.	200	300	a	a		a		a		14	22	o/l	
	75	4000	4 months of Feb. 4 months of May 4 months of Aug. 4 months of Nov.	260	360	a a a a	a a a a		a a a a		12 12 12 a		14 20 14 11	20 27 19 14	o/l	
	62	4000	2 months of May 2 months of Aug. 1 month of Nov.	260	120	a a a	a a a		a a a		19 20 14		26 24 18	30 27 20	o/s	
Italy	385	238	February 1955 May 1955 August 1955 November 1955	940	180	b b b b	b b b b		70 b b 70		89 85 73 83		90 87 76 84	90 88 76 85	n/s	
	370	238	August 1955 November 1955	60	180	b 56	b 58		b 71		66 81		69 83	70 84	n/s	
	189	250	August 1951 November 1951 February 1952 May 1952	2165	165					6.5 7 6 5	10 10 9 7	12 12 9 8			o/l	

	189	500	August 1951 November 1951 February 1952 May 1952	2165	165					6 5 4 5.5	12 11 8 9	15 12.5 9.5 11			o/s
	189	1000	August 1951 November 1951 February 1952 May 1952	2165	165					9.5 7 7.5 7.5	20 16 14 17	22 18 18 19.5			o/s
	142	7000	February 1957 May 1957	1150	165			5.4 6	8 10.4	10.1 15.4					o/l
Federal German Republic	79	2000	August 1957 November 1957	30	30			37.8 41.1	46.6 48.6	50.6 56.8					n/s
	79	7000	November 1957	30	30			23.2	34.8						n/s
	44	4000	May to Aug. 1954	910	585		3	1.5	1	4.5	10.5		18		o/l
Japan	45	200 4000	February 1952	70	50	13	14.5 —6	18 —2	20 c	21.5 3.5	23 6	23.5 6.5	24 10		
	63	200 4000	May 1952	1090	100		6 —4	7.5 —2	9 c	11 3	13 6	14 7	15.5 11		
	48	200 4000	May 1952	1090	600		4.5 —3	5.5 —1.5	7 c	8.5 2	9.5 4	10 4.5	10.3 5		
	150	200 1500 4000 6000	Aug.-Sept. 1954	1090	870		—6 —5 —9 —12	—2.5 —3 —5 —6	c c c c	5.5 7 7 9	15.5 20 22 23	18 23 25 27			
	100	1500 4000 6700	Aug.-Sept. 1956	320	340		—5.5 —9 —13	—2.5 —3.5 —4.5	c c c	4 5 5	14 14 13.5	17			
	100	4000 6700	November 1956	320	340	—7.5	—6 —5.5	—3 —3.5	c c	3.5 4	10 12.5	12.5 14.5			
	50	1500 4000 6700	July-August 1956	340	50		—5 —5.5 —7	—3 —3.5 —4.5	c c c	3.5 5.5 7	10 12 13	13.5 14 14	16		
	44	1500 6700	Aug. 1958	240	40	—4 —7	—3 —4.5	—2.5 —2.5	c c	3 3.5	7 7.5	7.5 8.5	10 11	16.5	

Notes:

a = less than 10 db
b = less than 45 dbc = within ± 2 db
o = line-of-sightn = over the horizon
l = land path.
s = sea path.

REPORT No. 144 *

INFLUENCE OF THE TROPOSPHERE ON WAVE PROPAGATION ACROSS MOUNTAIN RIDGES

(Study Programme No. 136 (V))

(Warsaw, 1956 — Los Angeles, 1959)

Mountain ridges, and particularly those which act as single knife-edges, can effectively reduce both the transmission loss and the fading below the values which would be expected in the absence of the obstacle. However, when referring to obstacle gain, it must be stated whether this refers to the gain on the calculated field over a homogeneous spherical earth where only diffraction and standard atmospheric refraction is involved (propagation curves of the C.C.I.R. Atlas) or whether scattering or super-refraction is considered as well (curves of Recommendation No. 312). The latter case occurs when it is possible to compare propagation over two neighbouring paths of comparable distances and antenna heights, one of which has a mountain ridge which causes knife-edge diffraction and the other is clear of obstacles. Measurements made under such conditions have confirmed that such gains do occur [Ref. 8, 9 and 11].

The measured values of transmission loss and the lobe structure, which can be measured by raising the receiving antenna, agree well with values calculated by diffraction theory for paths which lend themselves to relatively simple calculation [Ref. 1 and 2].

It is also found that when the field strength obtained is high, it is relatively stable and the fading is slight, whereas in a region where the field is normally weak, it fluctuates very much with variations in refractive index [Ref. 1, 2, 3, 4, and 5]. Since the high fields are produced by the addition in phase of fields received over several paths, relatively large effects of the troposphere on the individual components are required in order to produce an appreciable change in the amplitude of the resultant field. Conversely, the weaker fields, which are produced by partial cancellation of the individual field components, are greatly affected by changes in these components. This conclusion is supported by the fact that the high fields become less stable as the frequency is increased from the VHF (metric) to the SHF (centrimetric) band [Ref. 1]. On the basis of the information now at hand, it appears that the VHF (metric) band is likely to be more suitable than the higher frequencies for communication by waves diffracted over mountain ridges.

It will be further noted that the direction of arrival of the strongest signal need not be the direction of the great circle path between the transmitter and the receiver. This is most noticeable when the receiving station is very near to the diffraction ridge (a few miles). This indicates that in estimating the quality of a transmission across a mountain ridge consideration must be taken not only of the profile of the terrain in the great circle plane, but also of the diffraction properties of the ridge outside this plane.

For propagation over high mountain ridges, a large part of the path may be above the regions of the troposphere in which rapid changes in the index of refraction occur. Also, there may be marked differences in the weather on the two sides of a mountain ridge, so that the conditions which give rise to fading may occur only on one half of the path at a time. Both of these features may limit the effects of the troposphere on the individual components of the diffracted wave and

* This Report, which replaces Report No. 52, was adopted unanimously.

tend to minimize the fading which occurs at a receiving point where a high value of field is found [Ref. 3, 4 and 7]. While all these investigations are yielding very useful results, it is clearly necessary that studies should be continued in those countries which have the desired topographic features, so that the radio paths under investigation include mountain ridges. Also, since this mode of propagation is of primary interest to the fixed service, receiving sites should not be picked at random, but sites should be selected which give a high value of field strength and an expected low value of fading.

REFERENCES

1. Docs. 324, 325 (Japan) of Warsaw, 1956.
2. KIRBY *et al.*, *Proc. I.R.E.*, October, 1955.
3. Doc. No. 30 (Federal German Republic) of Warsaw, 1956.
4. Doc. No. 167 (C.C.I.R. Secretariat), of Warsaw, 1956.
5. DICKSON *et al.*, *Proc. I.R.E.*, August 1953.
6. Doc. V/19 (Japan) of Geneva, 1958.
7. Doc V/36 (C.C.I.R. Secretariat) of Geneva, 1958.
8. Doc. V/10 (United Kingdom) of Geneva, 1958.
9. Doc. IV/16 (France) of Geneva, 1958.
10. Doc. No. 132 (U.S.S.R.) of Los Angeles, 1959.
11. NORTON *et al.* *Proc. I.R.E.*, October 1955.

REPORT No. 145 *

TROPOSPHERIC WAVE PROPAGATION CURVES FOR DISTANCES WELL BEYOND THE HORIZON

(Study Programme No. 137 (V))

(Los Angeles, 1959)

This report presents the experimental data on which the curves of Recommendation No. 312 are based.

Results of field strength recordings extending over considerable periods of time have been made available by various Administrations, and those used for the production of the curves were obtained in France, the Federal German Republic, United States of America and United Kingdom.

In order that the curves should be representative of similar conditions in the various regions where the measurements were obtained, a selection of the data was made to ensure that an approximately homogeneous sample was used. The criteria determining this sample were as follows:

- all transmission paths to be over land,
- the period of recording to be at least six months, with not less than four hours of recording per day,

* This Report was adopted by correspondence without reservation (see page 9).

- height of receiving antenna above ground to be in the range 5 to 20 metres,
- height of transmitting antenna to be in the range 150 to 450 metres (The height of the transmitting antenna is here defined as its height above the average level of the ground between the distances of 3 and 15 km from the transmitter in the direction of the receiver),
- only one field strength value to be used for a given path regardless of the period for which the recordings were made.

Since no clear evidence of a dependence of long-range tropospheric fields on frequency was apparent in the data available, measurements at various frequencies between 40 and 600 Mc/s have been used to construct the curves which, for the time being therefore, must be regarded as representative of all of this band of frequencies. When more data become available, particularly at frequencies exceeding 100 Mc/s it may well be necessary to show a frequency dependence in the curves. Further data should also enable a definite dependence of the long-range field strengths on transmitting aerial height (for a given receiving aerial height) to be demonstrated.

Fig. 1, 2 and 3 show the field strengths exceeded for 1 %, 10 % and 50 % of the time respectively as determined by the sample of observations selected according to the above criteria, the field strengths being adjusted to correspond to 1 kW of power radiated from a half-wavelength dipole. In Fig. 1, measurements for 95 paths are plotted, and the root mean square deviation of the points from the smooth curve is 9.1 db; 96 points are plotted in Fig. 2, the r.m.s. deviation from the curve being 7.8 db, and for the 77 points of Fig. 3 the r.m.s. deviation from the curve is 8.5 db.

The three curves are considered to represent the best fit in each case to the experimental data, and they are the ones reproduced in Recommendation No. 312. The curves are based on much more extensive measurements than were available when the curves of Recommendation No. 111 were constructed but, as indicated above, there are still a number of respects in which further study is required. It is important that long-distance tropospheric field strengths should be measured for a wide range of frequencies, and more studies of the effects of terrain profile and of transmitting and receiving aerial heights and directivities are desirable.

Documents * submitted for consideration at Geneva, 1958, and Los Angeles, 1959, have contributed materially to the work under Study Programme No. 55. Amongst other things it has been demonstrated that the fields for entirely over-water paths are generally appreciably higher than those for over-land paths of comparable lengths; the importance of super-refraction in certain climatic regions has also been brought out, and it is evident that more studies in both of these respects are required, and also a general clarification of the effects of climatic conditions.

* Docs. V/7, V/8, V/17, V/35, V 38 and V 42 of Geneva, 1958; Docs. 103, 104, 131 and 182 of Los Angeles, 1959.

FIGURE 1
(1%)

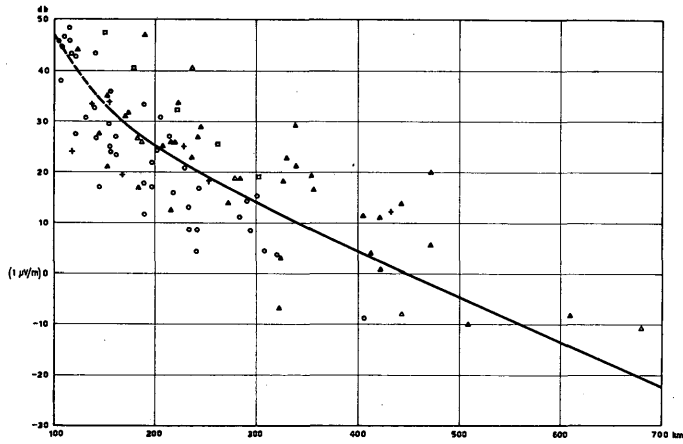


FIGURE 2
(10%)

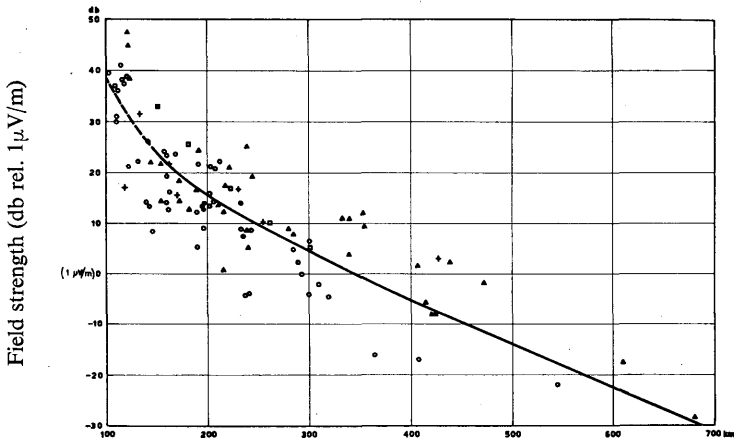
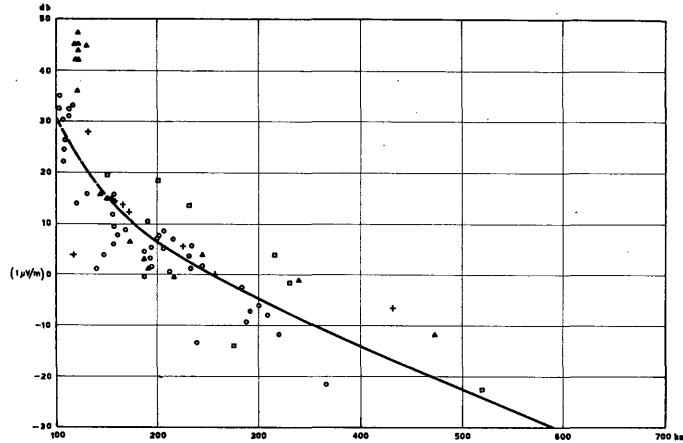


FIGURE 3
(50%)



Distance from the transmitter

- Data supplied by the United States of America.
- ◻ Data supplied by France.
- ⊕ Data supplied by the Federal German Republic.
- △ Data supplied by the United Kingdom.

FIGURES 1, 2 AND 3 Field strengths exceeded for 1%, 10% and 50% of the time (40-600 Mc/s)



REPORT No. 146 *

TROPOSPHERIC WAVE PROPAGATION

(Study Programme No. 138 (V))

(Los Angeles, 1959)

1. Reference atmospheres for field strength calculation.

In order to calculate field strengths or the associated transmission loss, it is necessary to specify the profile of the refractive index n of the atmosphere, with the height h above the surface of the earth as well as the characteristics of the terrain. In the past most field strength calculations have been made using an assumed constant gradient of refractive index with height and it has been established that the same field strengths are expected for this linear profile atmosphere as would be obtained for an earth with no atmosphere but with an effective radius, ka where a is the actual radius and k is determined by:

$$k = \left(1 + \frac{a}{n} \cdot \frac{dn}{dh} \right)^{-1} \quad (1)$$

Recently it has become desirable to extend the field strength calculations to very large heights and, in this case, the assumption of a constant gradient no longer represents a satisfactory description of the atmosphere and this, in turn, leads to large errors in the calculation of field strengths at these large heights.

It is well known that the average density of the atmosphere varies approximately exponentially with the height and it has recently been found that the mean values of the refractive index of the atmosphere may also be well approximated by the following exponential formula [15, 16].

$$n(h) = 1 + N_s \cdot e^{-bh} \times 10^{-6} \quad (2)$$

where $N = (n-1) \cdot 10^6$ and the suffix, s , refers to the values at the surface of the earth; h is the height above the surface expressed in kilometres, and b is determined by the relation:

$$e^{-b} = 1 + \Delta N / N_s \quad (3)$$

where ΔN is the difference in the N values at a height of one kilometre above the surface, and at the surface. Note that ΔN is a negative quantity.

Some recent studies, [7, 15 and 17] have shown that ΔN is in general correlated with the surface value N_s and may be estimated in some climatological regions by the following expression:

$$\Delta N = -7.32 \cdot \exp(-0.00558 N_s) \quad (4)$$

The above formula may be utilized for estimating ΔN in the usual case where only surface meteorological data are available. In particular, where $N_s = 289$ and $a = 6370$ km, one obtains $k = 4/3$ and $b = 0.136$; this is the basic reference atmosphere. If extensive radio-sonde data are available so that a good determination can be made of the average difference ΔN between the values

* This Report was adopted by correspondence without reservation (see page 9).

at the surface and at a height of one kilometre above the surface, these actual average measured values of ΔN and of N_s may be used in (2) and (3) for determining the characteristics of the atmosphere.

In summary, the above formulas provide a method for estimating mean refractive index profiles for any geographical locations in the world. When average values of ΔN and N_s are both known, these values may be substituted directly in (2) and (3) whereas in those cases where only N_s is known, equation (4) may be used to determine ΔN . In this latter case, these procedures presume the validity of the above-mentioned correlation of ΔN and N_s . For field strength calculations, it is customary to assume a horizontally homogeneous atmosphere and this assumption is usually realistic when dealing with average propagation conditions.

2. Correlation of tropospheric propagation with radio-meteorological parameters.

The variations of the refractive index in the lower atmosphere, and particularly those with height, influence the field strengths observed over radio circuits through the troposphere.

For many years, account has been taken of the average influence of the vertical variation of the refractive index by the introduction, for a standard radio atmosphere, of a linear gradient of approximately $-40N$ -units per kilometre, corresponding to the use of a value $4/3$ times its actual value of for the radius of the earth.

In a number of cases, it has been theoretically predicted and verified by experiments that the climatic and seasonal variations of fields observed on beyond line-of-sight paths are correlated with variations of the median value of the vertical gradient of the index [1, 2, 3, 4 and 5] between the surface of the earth and a height of 1000 metres above the earth. However, clear evidence of this correlation is confined to temperate climates, and has been established on the basis of monthly median, or at least weekly median values, and for given hours or periods of the day and not on the basis of daily or hourly values. Attempts have been made to obtain better hourly correlation using other parameters depending upon the atmospheric stability [6].

Recommendation No. 312 (Annex I, § 10) gives a formula for evaluating the approximate variations in the median values of the field strength, as a function of the vertical gradient of the index, for paths several hundred kilometres in length and for frequencies of 40 to 500 Mc/s.

In some cases, correlation has also been observed between the vertical gradient of refractive index and the value of this index at the surface of the earth [2, 7 and 17]. In these cases, a direct correlation between observed field strength and the surface values of refractive index has been established [8 and 9]. The surface refractive index is easier to determine from the existing statistical meteorological data than the gradient of the index; the latter requires radio-sonde measurements which are usually taken in the meteorological observatories of the world at specified hours each day. A detailed study of the correlation between field strength and the surface value of the refractive index has been carried out in the United States for distances far beyond the horizon. The correlation coefficients between the median values of the two quantities for periods of about 10 days have been found to be at least as large as 0.75. Good correlation has also been obtained in Japan [10], but the results in other regions of the world, particularly in Europe and Africa are not as conclusive. It is, therefore, considered necessary that further studies should be undertaken in regions of the world with diverse climates. Recommendation No. 312, (Annex I, § 10) provides a formula for the approximate evaluation of the variations in the median values of field strength, as a function of the surface values of refractive index, for paths several hundred kilometres in length, and for frequencies of 40 to 500 Mc/s, which take into account the preceding discussion.

The variations of the index of refraction are not only important in the consideration of field strength variations, but are also important in the consideration of the total bending of radio waves passing through the troposphere [11]. Studies carried out in the United States indicate a good correlation between the variations in the bending and variations in the vertical gradient and the surface values of refractive index. The vertical gradient leads to a somewhat better prediction

for elevation angles less than three degrees, while the surface value is much better than the gradient at elevation angles greater than three degrees. Further studies are, however, necessary.

In conclusion, it appears desirable that world-wide charts [12, 13] should be prepared of both the average vertical gradient of radio refractive index and the surface values of refractive index for various hours of the day in each season of the year. These charts would be for the use of radio engineers. The continuation of world-wide systematic studies of the correlation between these parameters and the variations in radio propagation, in accordance with Study Programme No. 138 (V), is urged.

An international working party, consisting of members of the Administrations of France (Chairman), United States, Japan, Netherlands, Federal Republic of Germany, the United Kingdom and Czechoslovakia, has been established to collect world-wide data from administrations on radio refractive index gradients and surface values of refractive index, and the preparation of world-wide charts of these parameters. The work of the international party will be conducted as far as possible by correspondence and coordinated in France by C.N.E.T. (Issy-les-Moulineaux, Seine).

Note. — At a meeting in Paris in June, 1957, of the Commissions for Instruments and Methods of Observation, and for Aerology, of the World Meteorological Organization, consideration was given to the needs of radio engineers in regard to atmospheric refractive index studies.

REFERENCES

1. SAXTON, J. A. Propagation of Metre Waves beyond the Normal Horizon. *Proc. I.E.E.*, Part III (1951).
2. BEAN, B. R. and MEANEY, F. M. Some Applications of the Monthly Median Refractivity Gradient in Tropospheric Propagation. *Proc. I.R.E.*, Vol. 43, 10, 1419-1431 (Oct. 1955).
3. AUGIER *et al.* *Résultats de propagation en ondes ultra-courtes du Cameroun*. Editions BCEOM, Paris.
4. TROITZKY, V. N. Fading of Ultra-short Waves in Radio Relay Systems. *Electrosviaz*, 10 (1957).
5. Doc. V/24 (Czechoslovakia) of Geneva, 1958. *Mean Refractivity in Prague*.
6. MISME, P. Corrélation entre le champ à grande distance et un nouveau paramètre radiométéorologique. *Annales des télécommunications* (July 1958); also *Transactions of PGAP* (July 1958).
7. DU CASTEL, F. and MISME, P. Eléments de radioclimatologie. *Ondes Electriques* (December 1957).
8. PICKARD, G. W. and STETSON H. T. A study of tropospheric reception at 428 Mc/s and meteorological conditions. *Proc. I.R.E.* 35 (December 1947).
9. BEAN, B. R. Some Meteorological Effects on Scattered Radio Waves. *I.R.E. Trans. on Comm. Systems*, Vol. CS-4, 1, 32-38 (March, 1956).
10. ONOE, M. *et al.* Results of Experiments of Long-Distance Overland Propagation of Ultra-Short Waves. *Journal of Radio Research Laboratories*, Vol. 5, 20 (April 1958).
11. BEAN, B. R. and CAHOON, B. A. The use of surface weather observations to predict the total atmospheric bending of radio waves at small elevation angles. *Proc. I.R.E.*, Vol. 45, 11 (Nov. 1957).
12. BEAN, B. R. Sur l'utilisation des observations météorologiques courantes et propagation radioélectrique. *L'Onde Electrique* (May 1957).
13. BEAN, B. R. and HORN, J. D. On the climatology of the surface values of radio refractivity of the earth's atmosphere. *Journal of Research*, D, National Bureau of Standards, Nov. 1959.
14. HAY, D. R. Air mass refractivity in Central Canada. *Canadian Jour. Phys.*, Vol. 36, 1678 (1958).
15. Doc. 34 (Japan) of Los Angeles, 1959.
16. BEAN, B. R. and THAYER, G. D. On models of the atmospheric radio refractive index. *Proc. I.R.E.*, (May 1959).
17. BEAN, B. R. and HORN, J. D. The refractive index climate near the ground. *Journal of Research of NBS*, D, Radio Propagation (September 1959).

REPORT No. 147 *

TROPOSPHERIC WAVE PROPAGATION**Climatic Charts of Refractive Index Parameter ΔN ****

(Study Programme No. 138 (V))

(Los Angeles, 1959)

1. Introduction.

This report represents the findings of a working group set up at the interim Study Group meeting held in Geneva in 1958 and having the following membership. France (Chairman), United States of America, Netherlands, Federal German Republic, United Kingdom and Czechoslovakia.

Although the terms of reference of the working party called for the preparation of world-wide iso- ΔN ** charts, as well as charts of the value of the refractive index at the earth's surface, the working party, after examination of the data available, considered it advisable to prepare charts of ΔN only. Further, these data enabled charts to be prepared on a regional basis for North America, Europe and North Africa, Japan and Australia only.

2. Preparation of the charts.

For the preparation of the three charts for the northern hemisphere, a projection on a plane tangential to the earth at the north pole was chosen. A similar procedure relative to the south pole was followed for the Australian charts.

Although the nominal hours of observation desired by the C.C.I.R. in Study Programme No. 138 (V) were 0200 and 1400 U.T., the error in using the observations supplied by some administrations for the hours 0300, 0400, 1500 and 1600 U.T. was negligible.*** The time zones are marked on the charts from 0000 G.M.T. onward.

Certain meteorological observations made over short periods of time have been made available to the working group. Although these results did not cover the entire period of 1951–55 desired by the C.C.I.R., they were used as a guide in region of sparse data. Regions where the contours were determined from such data are indicated by dashed contours.

3. Accuracy of the results.

While an important purpose of the charts is to indicate wide variations of radio climatology, they do provide values of ΔN with an accuracy better than 5 N -units.

It is not considered necessary to specify the apparatus used by the various administrations to determine ΔN since a working group of the W.M.O. set up by its Committee on Instruments and Methods of Observation (C.I.M.O.), meeting at Payerne (Switzerland) in June of 1956, determined from comparative measurements with 14 different radio sondes, that these all yielded data in good agreement at heights up to one kilometre above the ground.

4. Data used.

The data used for the preparation of the charts are listed in the following tables I-IV and the derived contours of ΔN are given in Fig. 1–32.

* This Report was adopted by correspondence without reservation (see page 9).

** ΔN is the difference, in parts per million, between the value of the refractive index at one kilometre above the earth's surface and the value at the earth's surface and is usually a negative quantity.

*** New proposals concerning the hours of observations have been made in Study Programme No. 138 (V).

5. Estimating the ground value of the refractive index.

For various reasons the working party on radio climatology considered it inadvisable to present world-wide charts of contours of constant value of refractive index at the earth's surface. Furthermore, investigation of data available indicates that such charts may be more accurate if the dependence with altitude of the ground values of the index is considered, and detailed examination of the applicability of this procedure in all parts of the world is desirable before charts of surface index are prepared for all parts of the world.

One investigation of this height dependence has been carried out for the continental United States by assuming that the variation of the ground values of the refractive index with ground altitude is of an exponential form. Under this assumption two sets of charts were prepared, one for summer and one for winter, using both the ground value of the refractive index and a value of the refractive index reduced to sea-level. The contours of these charts were then used to estimate the ground value of the refractive index at 20 stations *not used in the preparation of the charts*.

These results, tabulated in the table below indicate that it is 5 to 6 times more accurate to estimate the ground values of the refractive index by use of the intermediate step of contours of ground values reduced-to-sea-level.

R.M.S. error in predicting the ground values of the refractive index in parts per million

	Using contours of ground values	Using contours of values reduced to sea-level
Summer	17.5	2.7
Winter	13.6	2.8

Although the use of such values reduced to sea-level appears to offer a significant increase in accuracy, it must be remembered that this test assumed a particular altitude dependence of the ground values of the refractive index and was carried out only for the United States. The form of the altitude dependence may be different in different areas of the world with the result that the same reduction of error may not be universal.

Examples of the charts of the refractive index reduced to sea-level for the United States and for the world are given in Documents 196 and 197 of Los Angeles and are to be published.*

* BEAN, B. R. and HORN, J. D., The Refractive Index Climate Near the Ground. *NBS Journal of Research*, Part D, (Sept. 1959).

TABLE I *
Values of ΔN for the European-African sector

No.** of station	0200 U.T.				1400 U.T.			
	February	May	August	November	February	May	August	November
<i>French Community</i>								
1	44				35	32	38	41
2	69				60	84	54	60
3	25	28	35	25	19	27	25	24
<i>Note:</i> Data from the stations at Cayenne (Guiana), and Tananarive (Madagascar) are at the disposal of the C.C.I.R. These results have not been made use of in this report.								
<i>Denmark</i>								
4	38.8	43.0	49.8	38.8	36.7	38.1	41.0	38.8
5	33.4	34.4	39.9	35.8	33.7	36.2	38.6	35.8
<i>Note:</i> The figures for ΔN supplied by Station No. 5, relate to a difference of altitude of 935 metres. The results have been adapted to a value of 1000 m for the preparation of the charts.								
<i>France</i>								
6	43	54	56	47	43	51	66	49
7	41	47	50	49	38	37	43	49
8	36	42	40	37	37	44	44	41
9	35	41	43	39	31	38	39	37
10	34	39	41	31	33	35	38	38
11	48	45	48	41	43	45	46	42
<i>Morocco</i>								
12	49							
<i>Note:</i> Results prior to 1953 provided by France.								
<i>Netherlands</i>								
13	35	43	46	39	34	38	43	40
<i>United Kingdom</i>								
14	40.1	41.3	44.9	41.4	38.9	39.6	43.2	41.0
15	40.5	44.9	49.2	42.3	41.2	45.3	48.3	42.9
16	40.1	41.6	45.8	41.8	39.7	40.3	43.5	42.0
17	39.3	40.6	44.0	41.5	38.9	39.2	42.8	40.5
18	40.8	43.7	48.6	43.0	39.1	40.5	44.6	42.5
19	39.2	42.9	45.0	41.0	39.5	42.0	45.0	41.0
20	38.6	41.5	42.8	40.2	38.0	40.6	41.8	40.2
21	39.1	41.8	44.1	40.5	39.7	40.9	44.2	40.1
22	39.6	42.4	46.4	41.9	39.3	42.4	46.0	42.0
23	39.1	41.0	44.5	39.6	40.4	41.4	43.6	40.0
24	39.9	42.2	45.7	41.1	39.3	42.4	45.0	41.3
<i>Czechoslovakia</i>								
25	34.1	35.9	39.0	33.9	32.7	34.9	35.4	34.5
<i>Tunisia</i>								
26	40	53	77	48	46	43		51
<i>Note:</i> Results prior to 1953 provided by France.								
<i>Federal German Republic</i>								
81	38	43	48	41	38	37	40	42
82	37	42	44	37	35	34	37	39
83	37	42	46	40	36	35	39	40

* This data relates to measurements made at 0200 and 1400 U.T. from 1 Feb. 1953 to 31 Mar. 1957 and 0000 and 1200 U.T. beginning on 1 April 1957.

** For location of stations see Table V.

TABLE II
Values of ΔN for the American Sector

No. of station *	0200 U.T.				1400 U.T.			
	February	May	August	November	February	May	August	November
<i>United States of America</i>								
27	45.5	57.4	66.8	50.8	43.2	56.0	63.6	48.0
28	45.2	50.4	66.1	49.2	45.2	47.8	62.2	47.7
29	46.7	61.6	67.0	50.2	45.3	56.2	58.8	48.3
30	52.3	69.8	74.3	52.2	47.6	57.3	60.8	46.8
31	36.7	42.7	50.3	40.1	35.6	40.5	48.1	39.4
32	50.9	59.3	61.0	52.4	44.8	47.9	53.4	49.5
33	50.5	59.0	61.5	52.1	46.7	52.4	57.1	49.3
34	43.2	58.0	63.8	48.0	40.7	49.2	58.0	44.6
35	36.4	46.6	55.8	39.8	35.0	42.2	51.6	38.0
36	36.4	42.1	49.2	38.2				
37	41.4	47.9	53.0	42.4	41.2	47.0	50.4	42.3
38	49.0	49.0	65.6	52.5	46.6	48.5	61.6	47.2
39	38.6	48.1	56.0	42.2	38.4	50.0	56.2	41.6
40	38.2	41.4	51.8	39.7	38.2	41.6	51.2	39.2
41	39.3	49.0	53.6	40.8	39.5	47.6	53.2	41.8
42	37.1	38.6	47.2	38.2	36.6	36.6	45.4	37.7
43	38.0	42.2	51.9	40.5	38.1	41.8	50.8	39.4
44	36.2	40.1	49.9	37.1	35.7	38.6	45.0	37.6
45	36.1	40.6	48.5	37.8	35.9	37.6	47.8	37.3
46	38.3	47.0	43.9	39.6	41.3	52.6	58.7	42.1
47	37.7	49.2	55.5	41.1	35.7	43.5	53.0	39.5
48	38.0	46.0	53.7	43.0	38.7	45.0	51.7	40.8
49	40.5	32.3	42.3	44.8	43.7	34.4	47.7	43.2
50	37.7	36.7	48.9	36.6	39.1	36.5	49.4	37.0
51	36.1	40.8	46.4	37.4	36.2	38.5	45.9	37.2
52	38.5	48.2	52.7	39.7	39.0	49.0	53.8	41.6
53	40.3	35.2	29.3	42.4	38.9	40.8	38.3	40.8
54	38.1	37.6	46.9	37.6	38.8	37.8	49.5	37.5
55	36.4	34.7	31.0	38.4	36.5	39.2	40.8	38.3
56	36.8	33.6	38.5	36.0	38.0	34.9	43.3	36.9
57	32.2	25.8	26.0	32.6	36.7	28.9	32.1	35.4
58	36.1	40.7	36.6	36.8	40.0	47.8	48.0	39.2
59	36.0	44.0	47.2	38.1	37.4	45.0	51.7	39.7
60	36.5	40.2	50.9	38.1	36.9	38.7	52.8	38.6
61	36.0	36.8	41.4	37.6	36.1	36.8	38.2	38.0
62	34.3	37.4	41.8	35.5	34.7	38.3	47.2	36.0
63	31.8	31.2	32.7	32.5	32.0	33.5	37.4	32.7
64	30.1	26.2	34.2	30.7	33.8	29.2	40.6	31.6
65	33.2	28.6	32.6	32.5	32.9	30.5	36.3	33.6
66	28.4	26.8	36.6	28.2	31.2	29.8	39.1	30.4
67	30.9	32.3	31.6	32.3	32.0	34.5	37.2	32.9
68	31.5	30.4	30.8	32.1	32.6	31.9	32.7	33.0
69	37.0	41.6	55.4	38.6	37.0	43.1	54.2	39.2

Note: The values of ΔN actually relate to the hours of 0300 and 1500 U.T. The United States Administration can make information from certain additional stations available to the C.C.I.R..

* For location of stations see Table V.

TABLE III
Values of $-\Delta N$ for the Pacific sector

No. of station *	0200 U.T.				1400 U.T.			
	February	May	August	November	February	May	August	November
<i>Japan</i>								
70	39	47	49	42	39	47	53	44
71	37	46	55	40	37	46	53	42
72	36	47	59	40	35	45	58	40
73	34	43	50	39	38	44	49	40
74	36	45	53	41	38	46	50	42
75	32	40	49	36	35	39	51	38
76	34	43	53	39	35	43	51	39
77	32	38	45	35	34	38	44	36
78	32		48	39	33	39	45	34
79			59				63	
80	49	55	57		49	56	57	

Note 1: For all the above stations, ΔN has been calculated between the station altitude and an altitude above sea-level of 1000 metres. The values used in plotting the chart have been adapted for a difference in altitude of 100 metres.

Note 2: All the values above relate to the hours of 0300 and 1500 U.T.

TABLE IV
Values of $-\Delta N$ for the South Pacific sector

No. of station *	0200 U.T.				1400 U.T.			
	February	May	August	November	February	May	August	November
<i>Australia</i>								
84	28	35	35	32		48	44	49
85	8	11	12	9	27	21		17
86	33	32	32	27		52	51	
87	17	17	16	16	32	27	38	27
88	25	20	17	18	62	18	31	35
89	48	48	51	46				
90	48	28	30	44	74	70	68	63
91	37	37	37	36				
92	33	32	31	30				
93	13	18	17	13				
94		44	35	47				
95	40	42	41	41				
96			40	50				
97	36	36	34	32	53	46		47
98	44	44	36	45				
99	33	34	36	32				
100	46	35	36	39	61	50	47	64
100 bis	48	37	33	40				
101	52	36	36	50	63	55	54	56
102	19	24	22	20				
103					52	49	43	63

Note 1: The above values were calculated on the assumption that the mean index could coincide with the index worked out from the mean values for pressure temperature and humidity. The minimum values are subject to an error of 2 to 3 units of N at most.

Note 2: Station No. 92 has been omitted from the chart because of the lay-out chosen.

Note 3: For all the stations above ΔN was calculated between the station altitude and an altitude above sea-level of 1 000 m. The values used for plotting the charts were transformed so as to apply to a difference in altitude of 1 000 m.

Note 4: All the values above apply to 0400 and 1600 hours U.T.

Note 5: No use was made of the values of ΔN for stations Nos. 87 and 93 in plotting the charts.

| *French Commonwealth* | | | | | | | | |
| 104 | 47 | 44 | 44 | 43 | | | | |

* For location of stations see Table V.

TABLE V
Location of stations

No. of station	Name	Position		Altitude (m)	Notes
		Latitude	Longitude		
1	Bangui	04° 22' N	18° 34' E	386	
2	Dakar	14° 40' N	17° 26' W	40	
3	Fort-Frinquet	25° 14' N	11° 37' W	360	
4	Kastrup	55° 38' N	12° 39' E	0	
5	Thorshavn	62° 01' N	06° 46' W	65	
6	Alger	36° 43' N	03° 15' E	25	
7	Bordeaux	44° 50' N	00° 42' W	49	
8	Brest	48° 26' N	04° 25' W	103	
9	Nîmes	43° 51' N	04° 24' E	60	
10	Trappes	48° 46' N	02° 00' E	168	
11	Weather ship	45° 00' N	16° 00' W	0	
12	Casablanca	33° 34' N	07° 40' W	58	
13	de Bilt	52° 06' N	05° 11' E	5	
14	Aldergrove	54° 39' N	06° 13' W	79	
15	Camborne	50° 05' N	05° 32' W	87·8	
16	Downham Market	52° 37' N	00° 22' E	36·9	16 replaced by 16 <i>bis</i> on 19 Nov. 51
16 <i>bis</i>	Hemsby	52° 41' N	01° 41' E	12·8	
17	Fazakerly	53° 28' N	02° 55' W	17·1	
18	Larkill	51° 12' N	01° 48' W	133	18 replaced by 18 <i>bis</i> on 29 Apr. 53
18 <i>bis</i>	Crawley	51° 05' N	00° 12' W	144	
19	Lerwick	60° 08' N	01° 11' W	81·7	
20	Leuchars	56° 23' N	02° 53' W	5·8	
21	Stornoway	58° 13' N	06° 20' W	13·7	
22	Valentia	51° 56' N	10° 15' W	13·7	
23	Weather ship	59° 00' N	19° 00' W	11	
24	Weather ship	52° 30' N	20° 00' W	11	
25	Praha	50° 07' N	14° 32' E	374	
26	Tunis	36° 50' N	10° 14' E	4	
27	Hatteras, N.C.	35° 15' N	75° 40' W	3	
28	Oakland, Calif.	37° 40' N	122° 12' W	5	
29	Lake Charles, La.	30° 13' N	93° 09' W	6	
30	Brownsville, Tex.	25° 55' N	97° 28' W	6	
31	Portland Maine	43° 39' N	70° 19' W	6	
32	Miami, Florida	25° 49' N	80° 17' W	7	
33	Tampa, Florida	27° 58' N	82° 32' W	11	
34	Charleston, S.C.	32° 54' N	80° 02' W	14	
35	Dist. Columbia	38° 54' N	77° 03' W	22	
36	Albany, N.Y.	42° 45' N	73° 48' W	27	
37	Tatoosh Is., Wash.	48° 23' N	124° 44' W	36	
38	Santa Maria, Calif.	34° 54' N	120° 28' W	79	
39	Little Rock, Ark.	34° 44' N	92° 14' W	81	
40	Joliet, Ill.	41° 30' N	88° 10' W	179	
41	Nashville, Tenn.	36° 07' N	86° 41' W	183	
42	Carabou, Maine	46° 53' N	67° 58' W	191	
43	Toledo, Ohio	41° 34' N	83° 28' W	191	
44	Buffalo, N.Y.	42° 56' N	78° 43' W	215	
45	Sault St. Marie Mich.	46° 28' N	84° 22' W	221	
46	San Antonio Texas	29° 32' N	98° 28' W	242	
47	Greensboro, N.C.	36° 05' N	79° 57' W	275	
48	Atlanta, Georgia	33° 39' N	84° 25' W	303	
49	Phoenix, Ariz.	33° 26' N	112° 02' W	339	
50	International Falls, Min.	48° 36' N	93° 24' W	343	
51	Pittsburgh, Pa.	40° 21' N	79° 56' W	388	
52	Oklahoma City, Ok.	35° 24' N	97° 36' W	397	
53	Medford, Oregon	42° 23' N	122° 52' W	405	

TABLE V

No. of station	Name	Position		Altitude (m)	Notes
		Latitude	Longitude		
54	Bismark, N. Dak.	46° 46' N	100° 45' W	506	
55	Spokane, Wash.	47° 37' N	117° 31' W	600	
56	Glasgow, Mont.	48° 11' N	106° 38' W	643	
57	Las Vegas, Nevada	36° 04' N	115° 10' W	664	
58	Big Springs, Texas	32° 14' N	101° 30' W	773	
59	Dodge City, Kansas	37° 46' N	99° 58' W	790	
60	North Platte Neb.	41° 08' N	100° 42' W	849	
61	Boise, Idaho	43° 34' N	116° 13' W	871	
62	Rapid City, S. Dak.	44° 09' N	103° 06' W	981	
63	Great Falls, Mont.	47° 30' N	111° 21' W	1124	
64	El Paso, Texas	31° 47' N	106° 30' W	1194	
65	Grand Junction, Col.	39° 06' N	108° 32' W	1474	
66	Albuquerque, N. Mex.	35° 03' N	106° 37' W	1620	
67	Lander, Wyo.	42° 48' N	108° 43' W	1694	
68	Ely, Nevada	39° 17' N	114° 51' W	1909	
69	Omaha				
70	Kagoshima	31° 34' N	130° 33' E	5.4	
71	Yonago	35° 26' N	133° 21' E	7.9	
72	Shionomisaki	33° 27' N	135° 46' E	74.9	
73	Tateno	36° 03' N	140° 08' E	27.2	
74	Wajima	37° 23' N	136° 54' E	6.9	
75	Sendai	38° 16' N	140° 54' E	39.8	
76	Akita	39° 41' N	140° 06' E	9.9	
77	Sapporo	43° 01' N	141° 20' E	18.1	
78	Wakkanai	45° 25' N	141° 41' E	3.2	
79	Weather ship	29° 00' N	135° 00' E	0	
80	Marcus Island	24° 18' N	153° 58' E	16.7	
81	Emdem	53° 20' N	07° 15' E	2	
82	Hannover	52° 22' N	09° 45' E	52	
83	München	48° 08' N	11° 34' E	524	
84	Adelaide	34° 57' S	138° 31' E	4	1600 U.T. information for 1945
85	Alice Springs	23° 48' S	133° 53' E	555	do. for 1945-46
86	Amberley	27° 38' S	152° 43' E	26	
87	Charleville	26° 25' S	146° 17' E	305	
88	Cloncurry	20° 40' S	140° 30' E	193	do. for 1944-45
89	Cocos Island	12° 11' S	96° 50' E	3	
90	Darwin	12° 28' S	130° 55' E	27	
91	Heard Island	53° 06' S	72° 31' E	5	0400 U.T. do. for 1954- 55
92	Hobart	42° 53' S	147° 20' E	53	
93	Kalgoorlie	30° 46' S	121° 27' E	370	
94	Lord Howe Island	31° 31' S	159° 03' E	47	do. for 1955
95	Macquarie Island	54° 30' S	158° 57' E	6	do. for 1953-54
96	Mawson	67° 36' S	62° 53' E	16	do. for 1953
97	Laverton	37° 52' S	144° 46' E	14	1600 U.T. do. 1944-45
98	Norfolk Island	29° 03' S	167° 56' E	110	
99	Guildford	31° 56' S	115° 57' E	11	
100	Rathmines	33° 03' S	151° 36' E	3	For 1953. Replace by 100 bis in 1954
100 bis	Williamtown	32° 48' S	151° 51' E	7	0400 U.T. for 1954-55
101	Garbutt	19° 15' S	146° 46' E	4	1600 U.T. for 1944-45
102	Woomera	31° 20' S	135° 55' E	169	
103	Pearce	31° 40' S	116° 01' E	56	1600 U.T. do. for 1945-46
104	New Amsterdam	37° 50' S	77° 34' E	28	

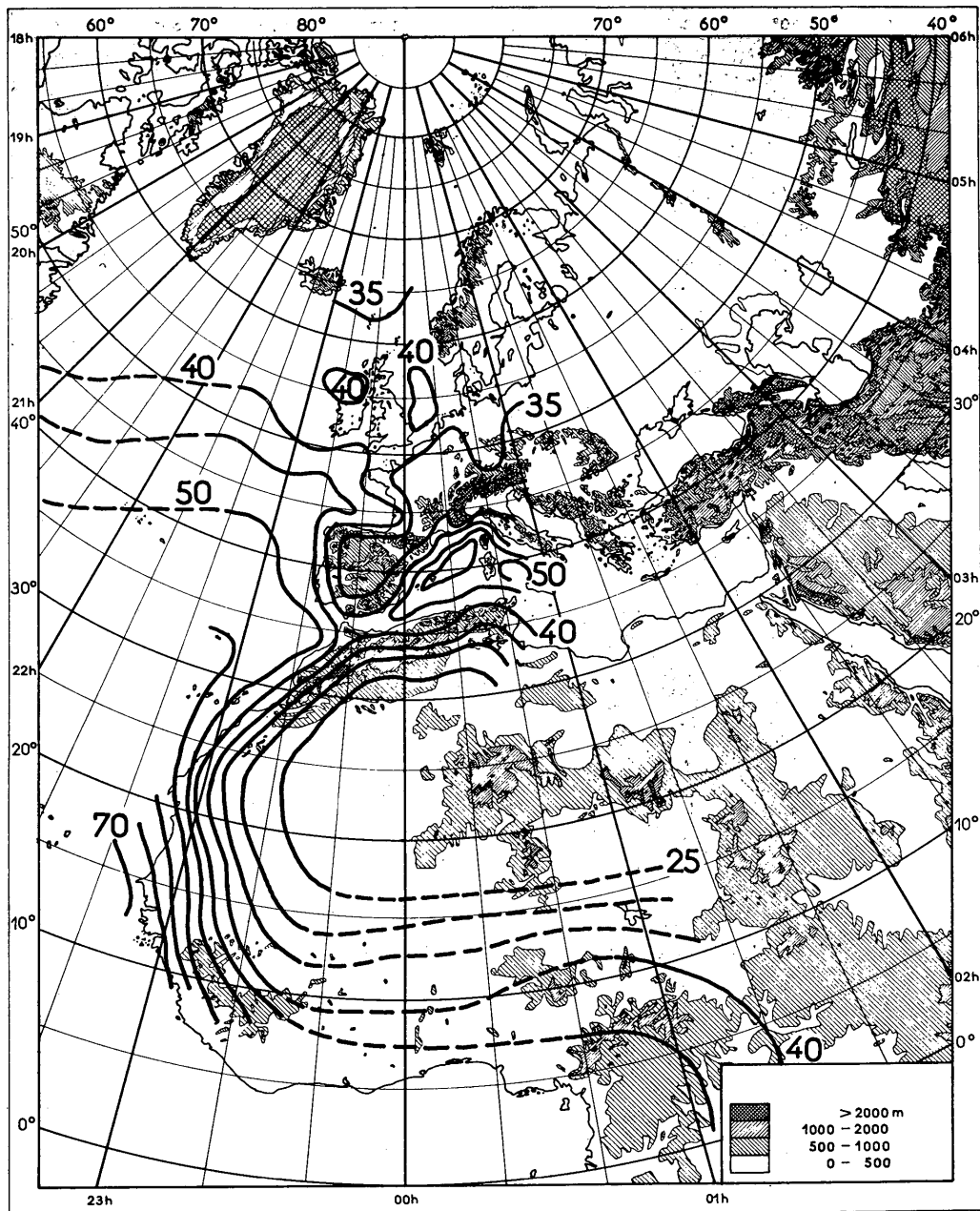


FIGURE 1

Iso — ΔN chart for the European-African sector for the month of February. 0200 hrs U.T.

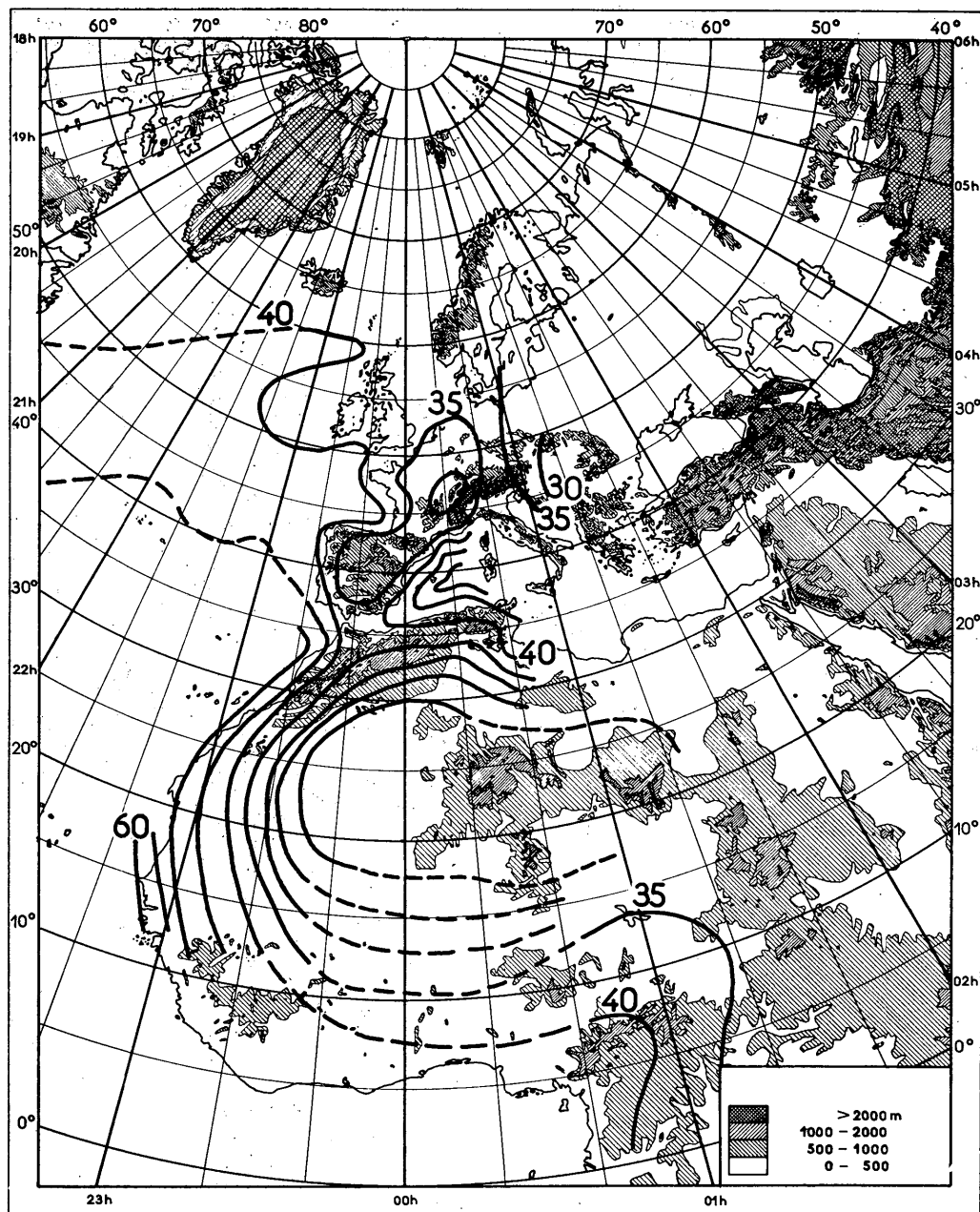


FIGURE 2

Iso — ΔN chart for the European-African sector for the month of February, 1400 hrs U.T.

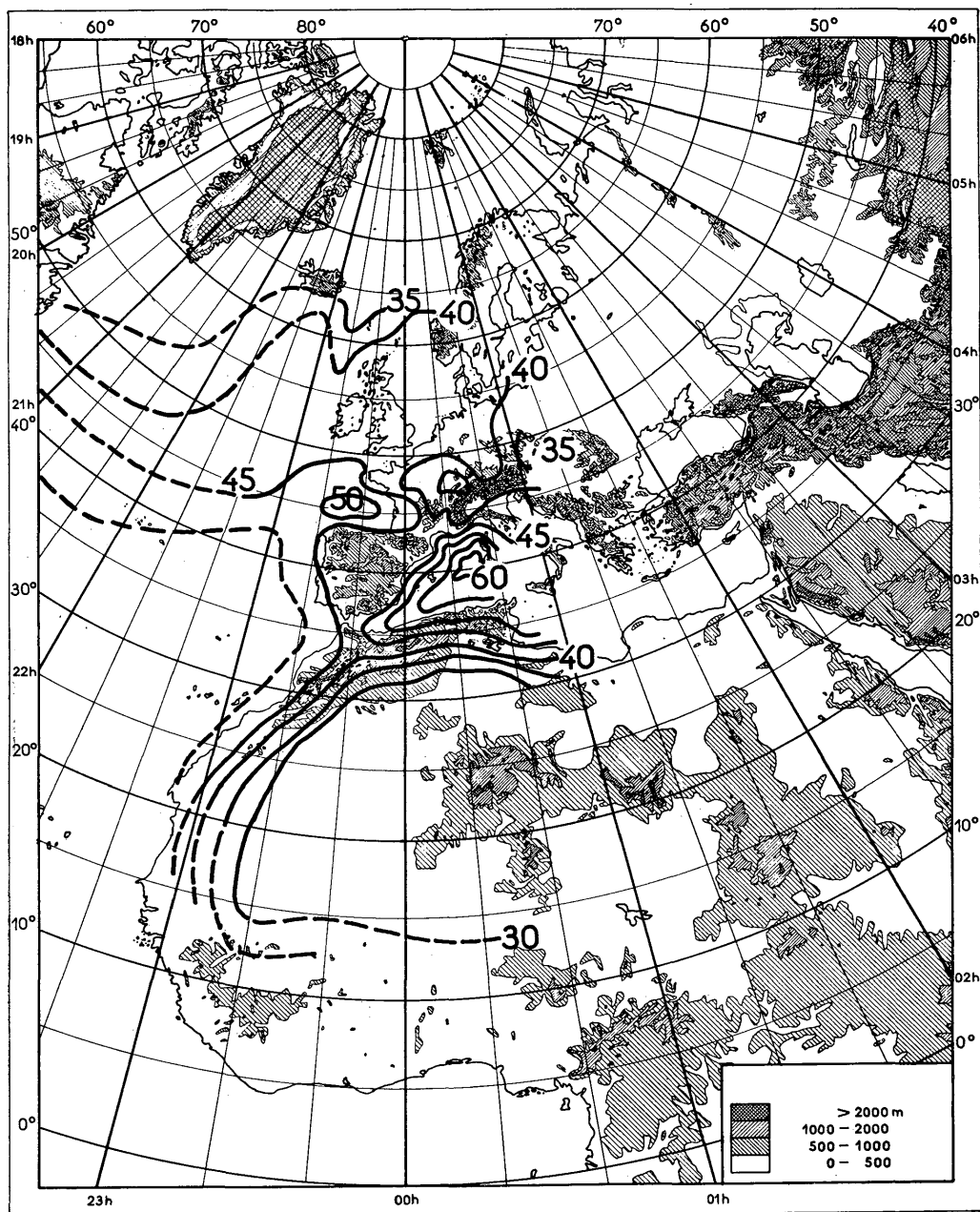


FIGURE 3

Iso — ΔN chart for the European-African sector for the month of May, 0200 hrs U.T.

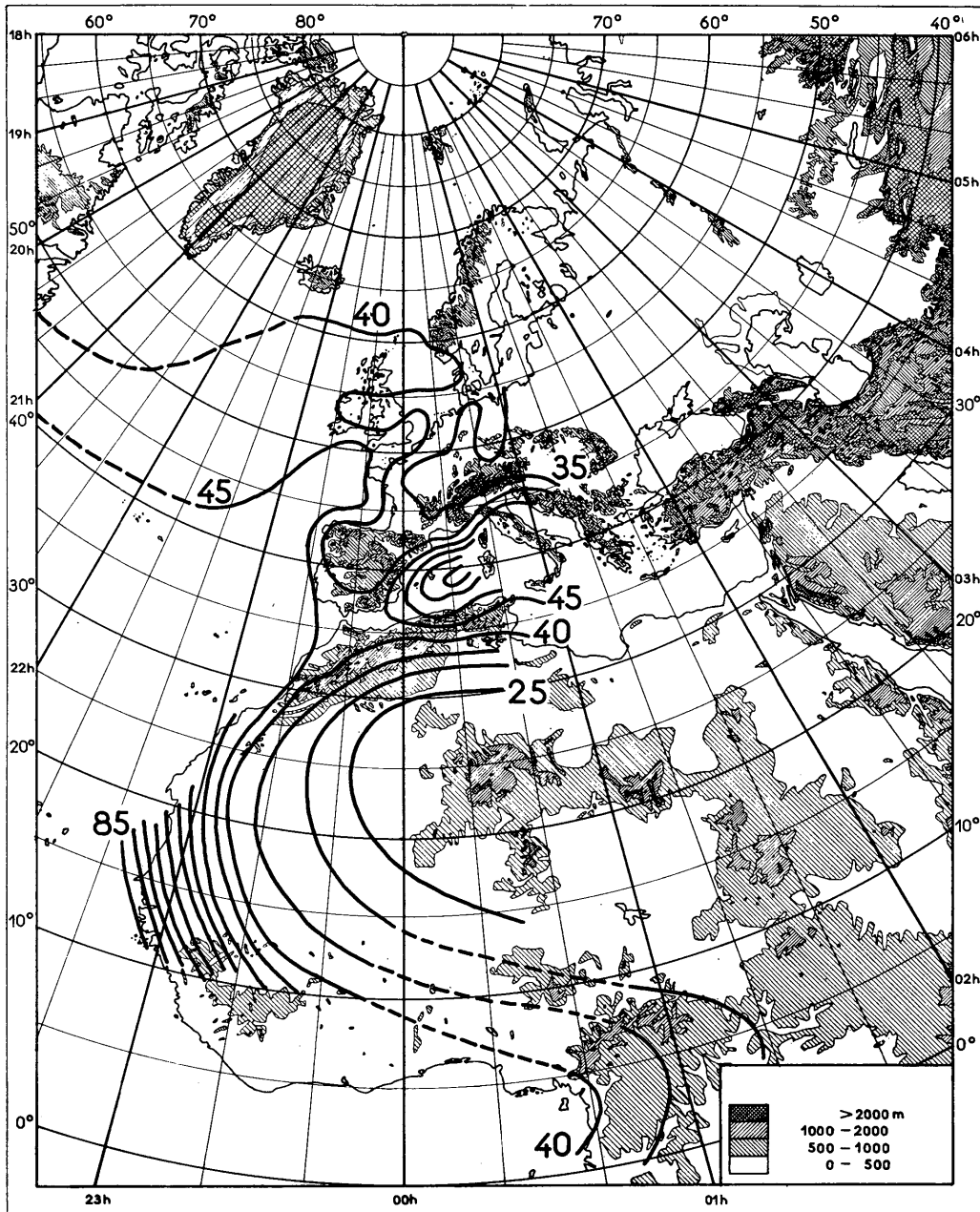


FIGURE 4

Iso — ΔN chart for the European-African sector for the month of May, 1400 hrs U.T.

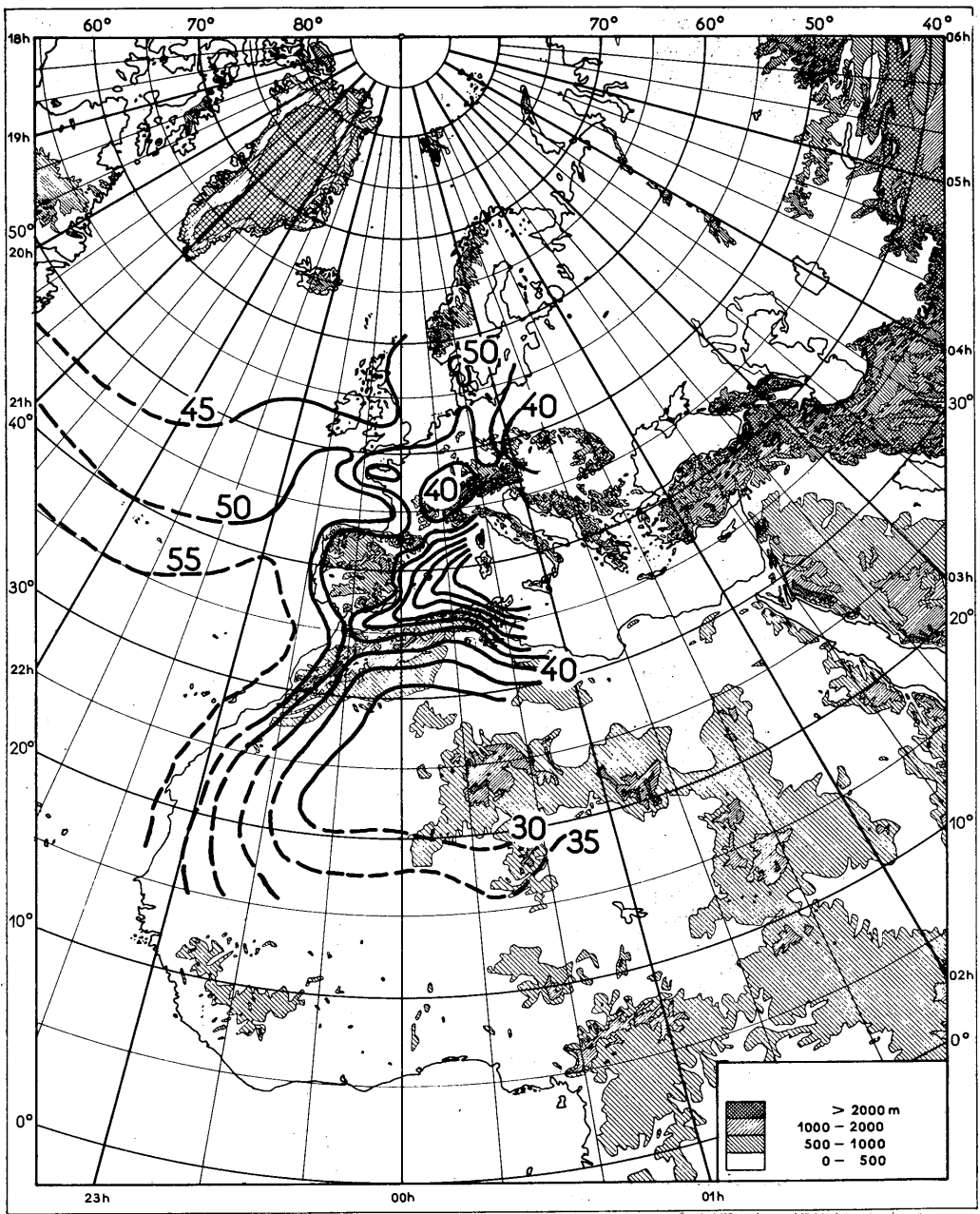


FIGURE 5

Iso — ΔN chart for the European-African sector for the month of August, 0200 hrs U.T.

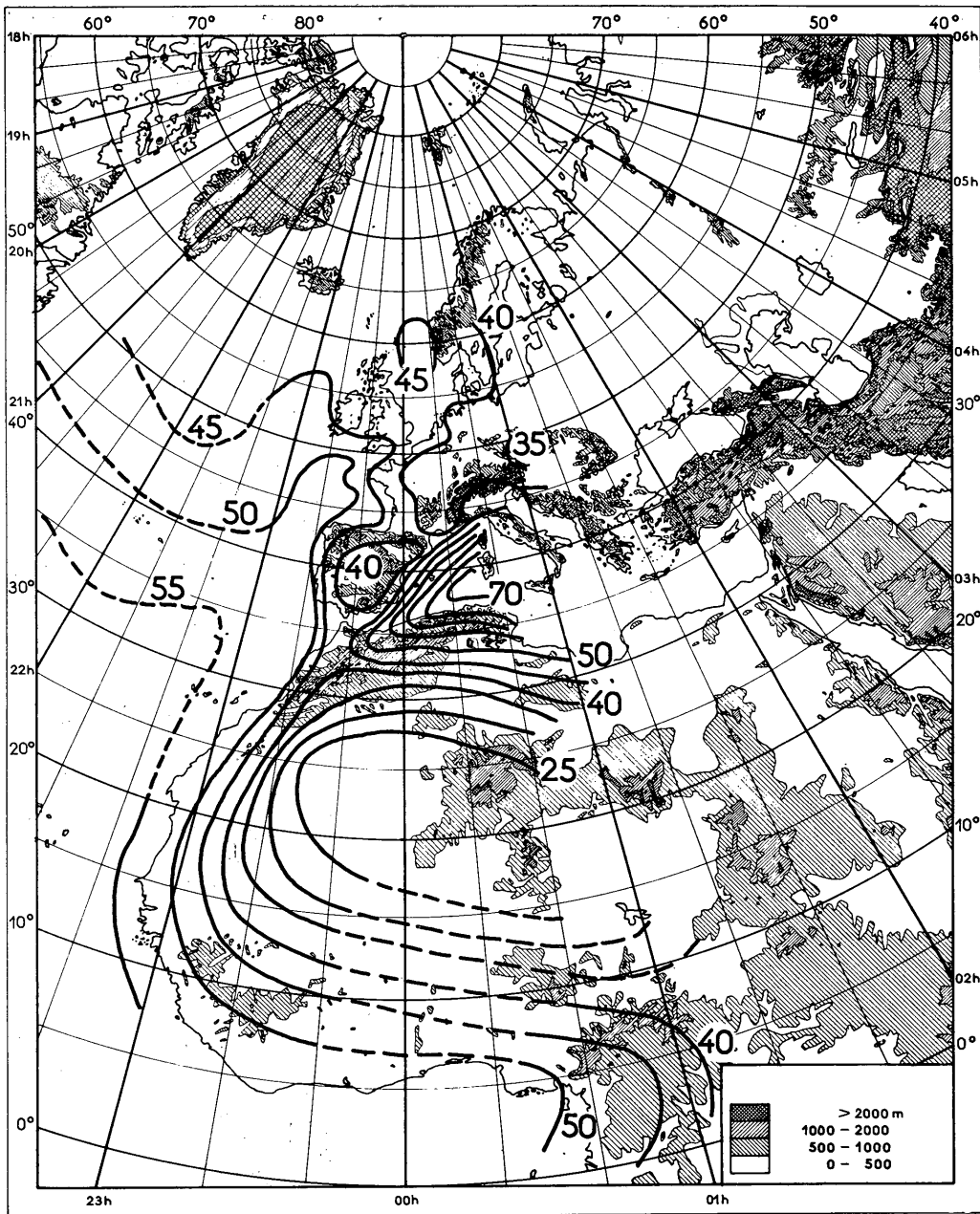


FIGURE 6

Iso — ΔN chart for the European-African sector for the month of August, 1400 hrs U.T.

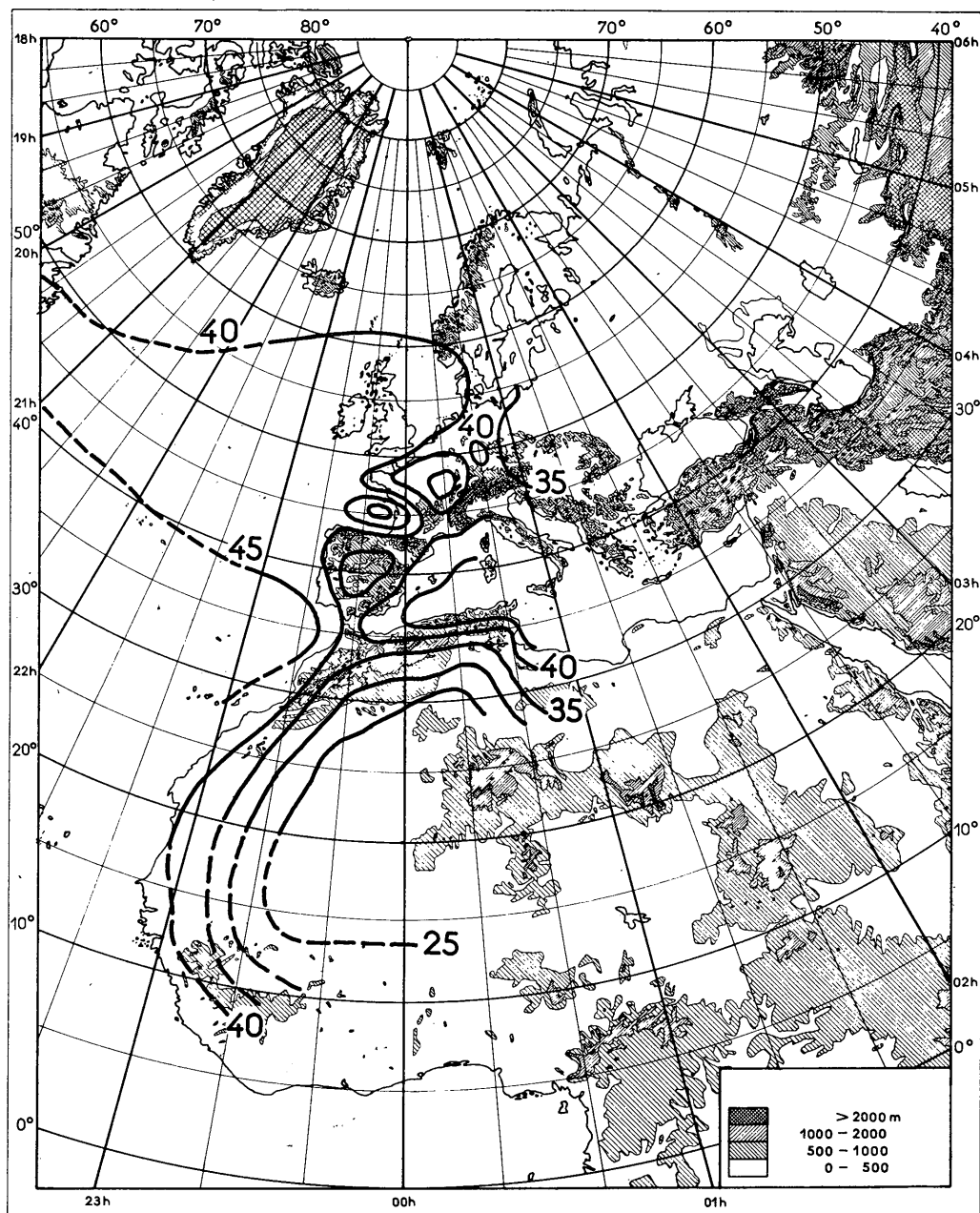


FIGURE 7

Iso — ΔN chart for the European-African sector for the month of November, 0200 hrs U.T.

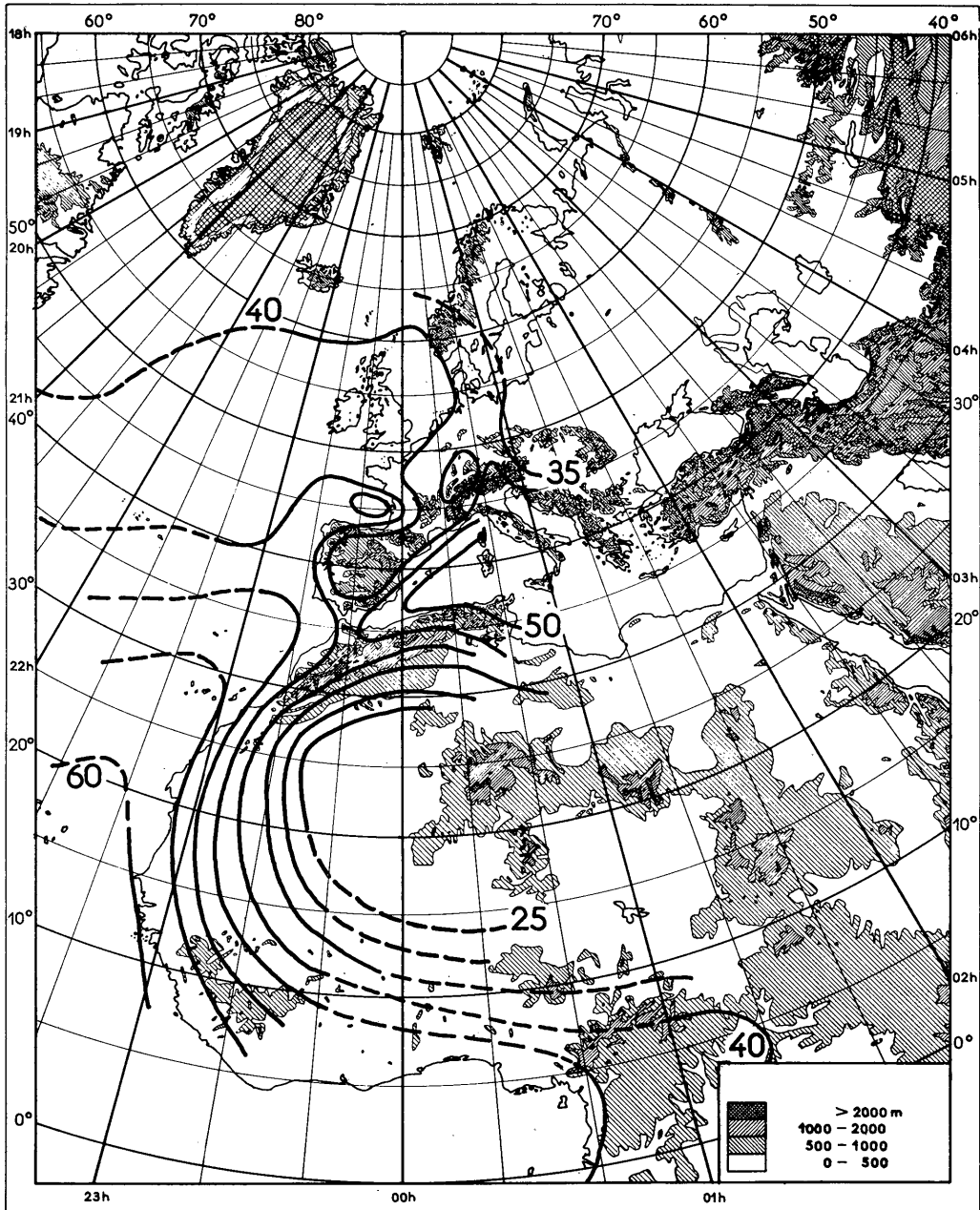


FIGURE 8

Iso — ΔN chart for the European-African sector for the month of November, 1400 hrs U.T.

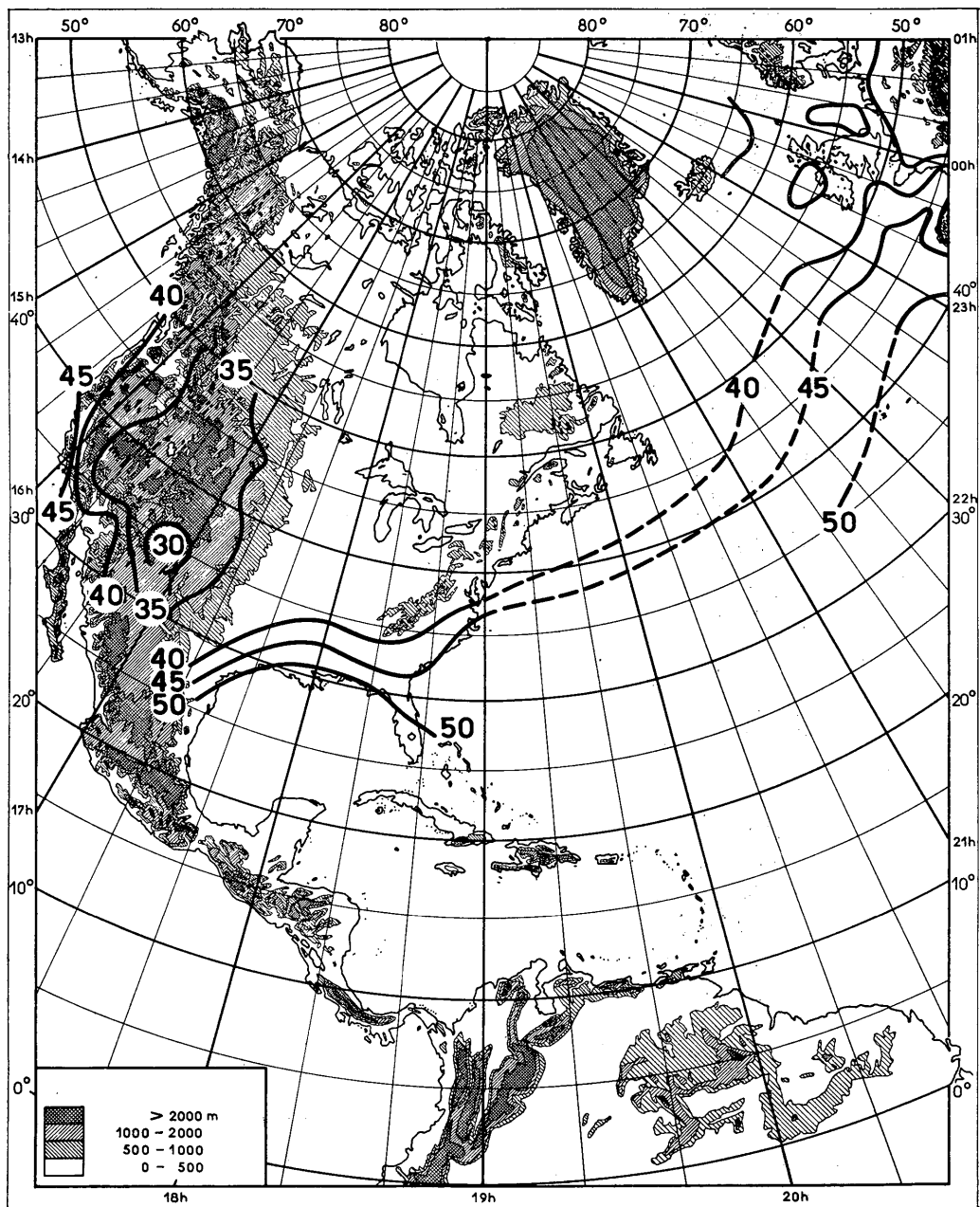


FIGURE 9

Iso — ΔN chart for the American sector for the month of February, 0300 hrs U.T.

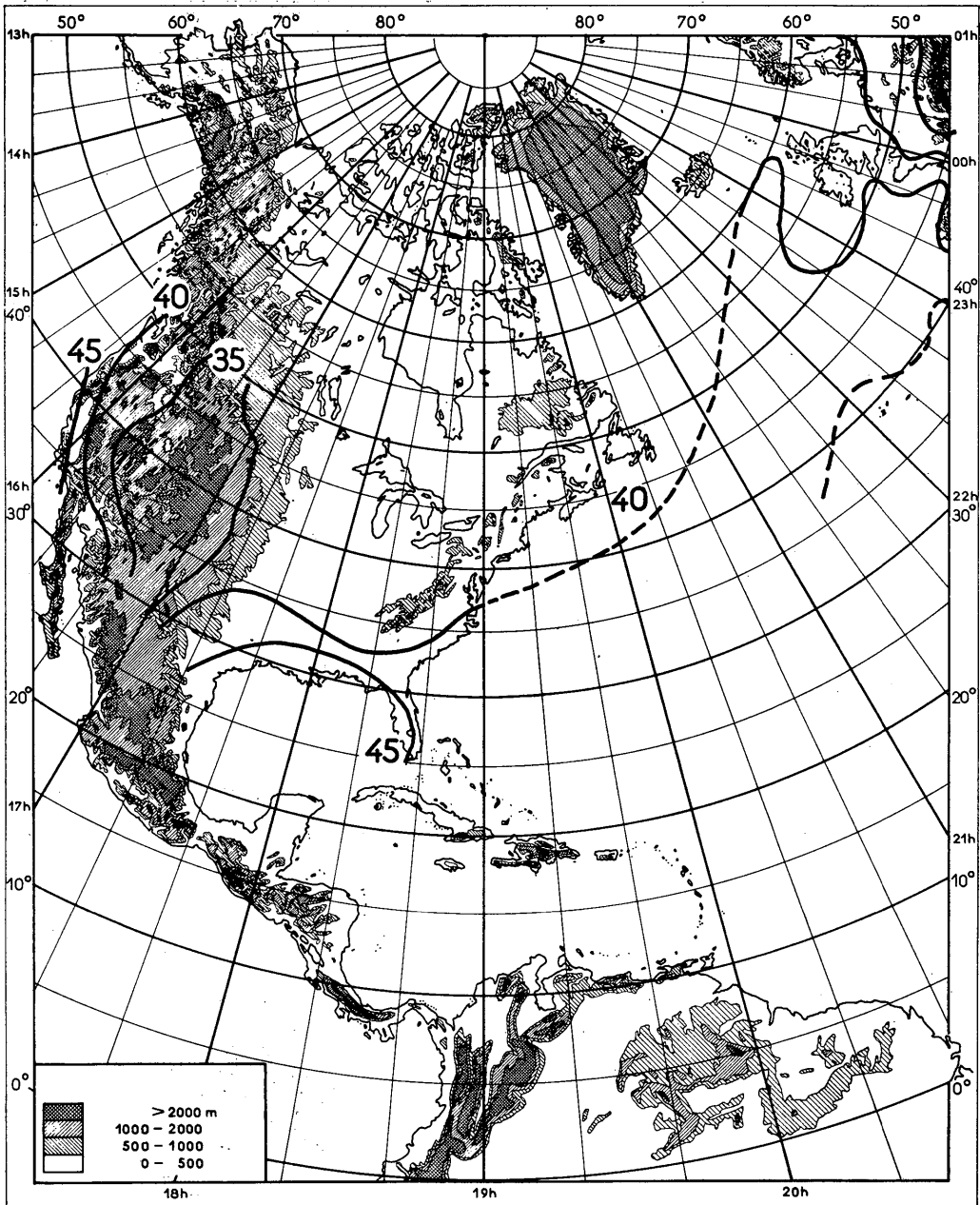


FIGURE 10

Iso — ΔN chart for the American sector for the month of February, 1500 hrs U.T.



FIGURE 11

Iso — ΔN chart for the American sector for the month of May, 0300 hrs U.T.

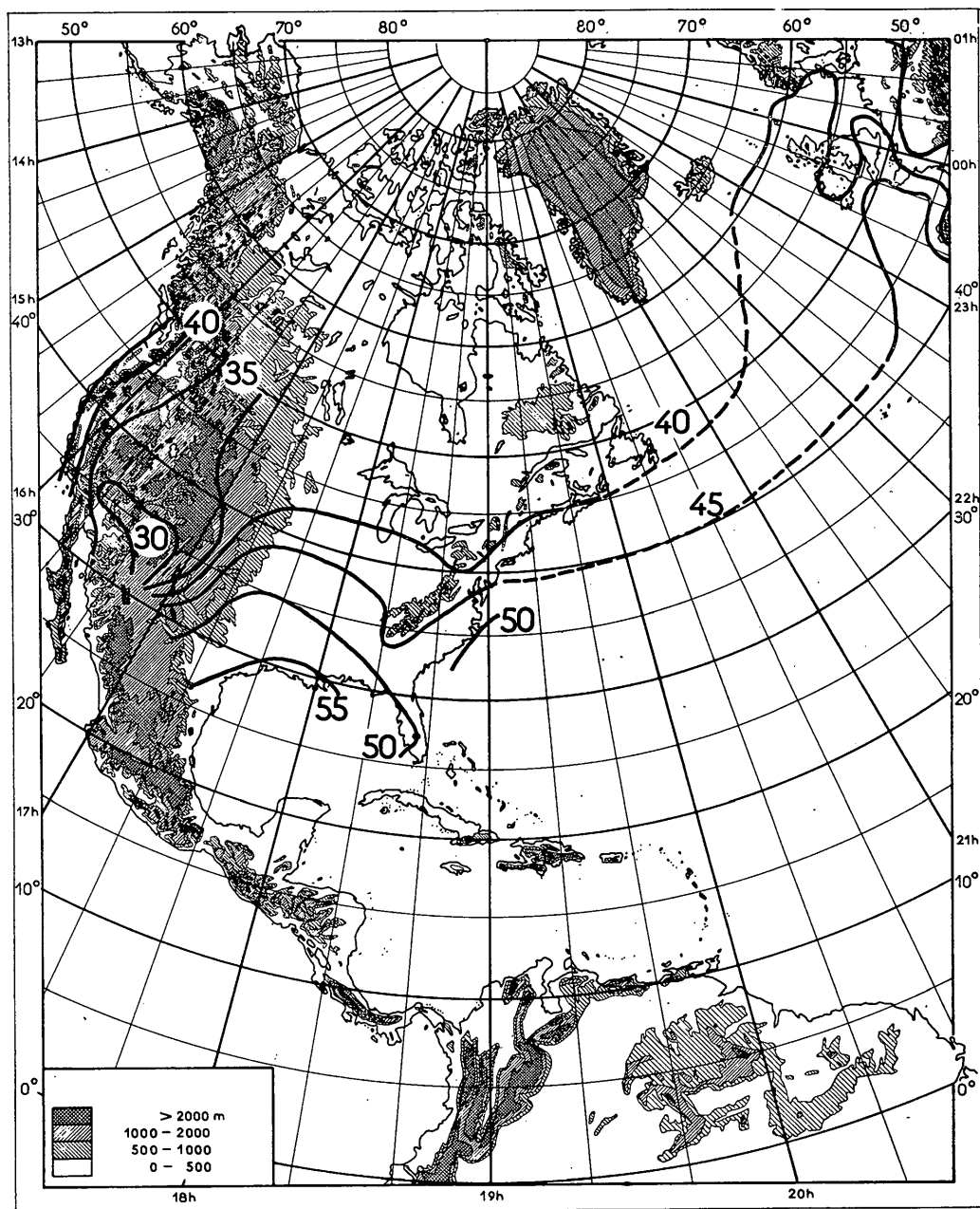


FIGURE 12

Iso — ΔN chart for the American sector for the month of May, 1500 hrs U.T.

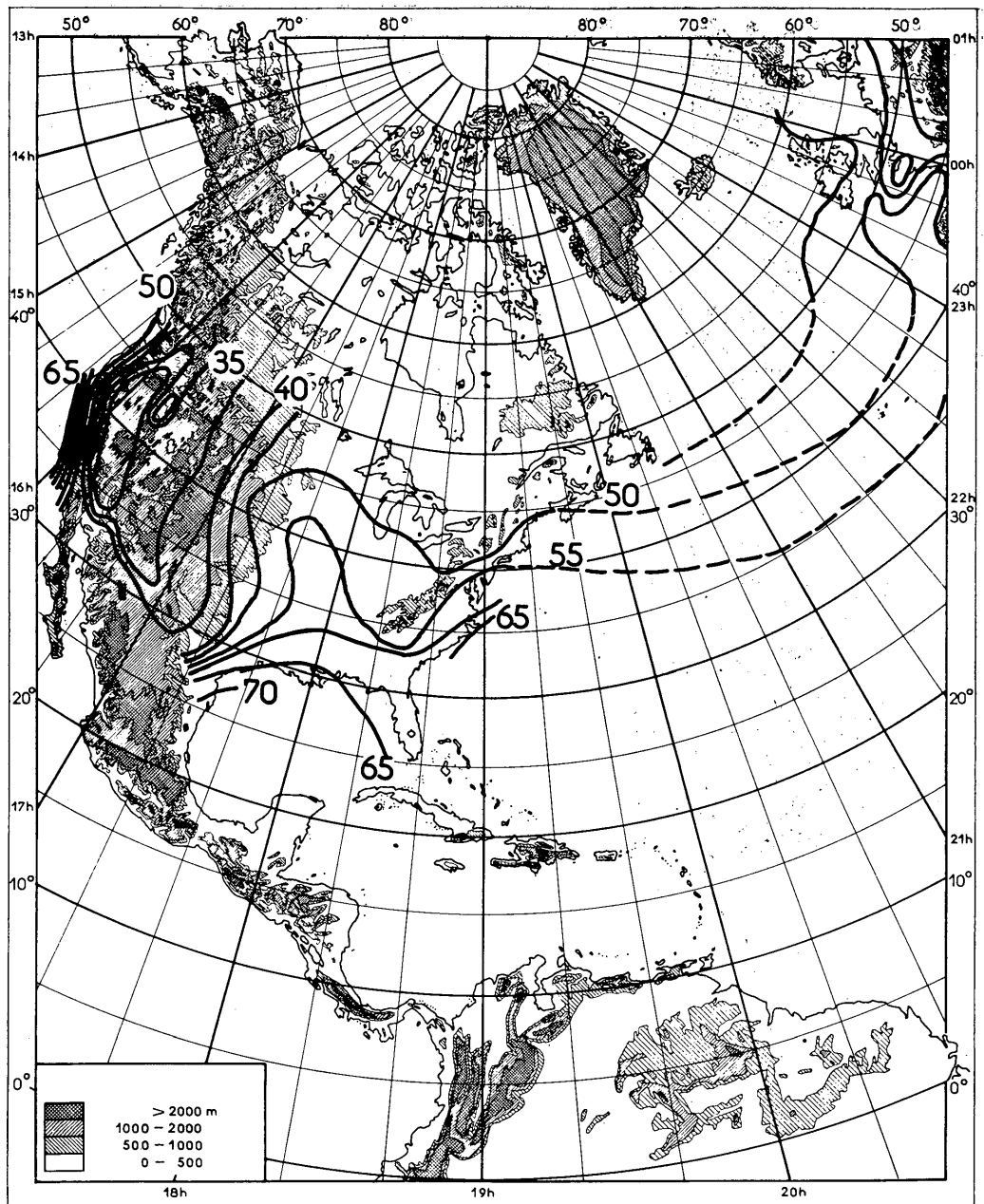


FIGURE 13

Iso — ΔN chart for the American sector for the month of August, 0300 hrs U.T.

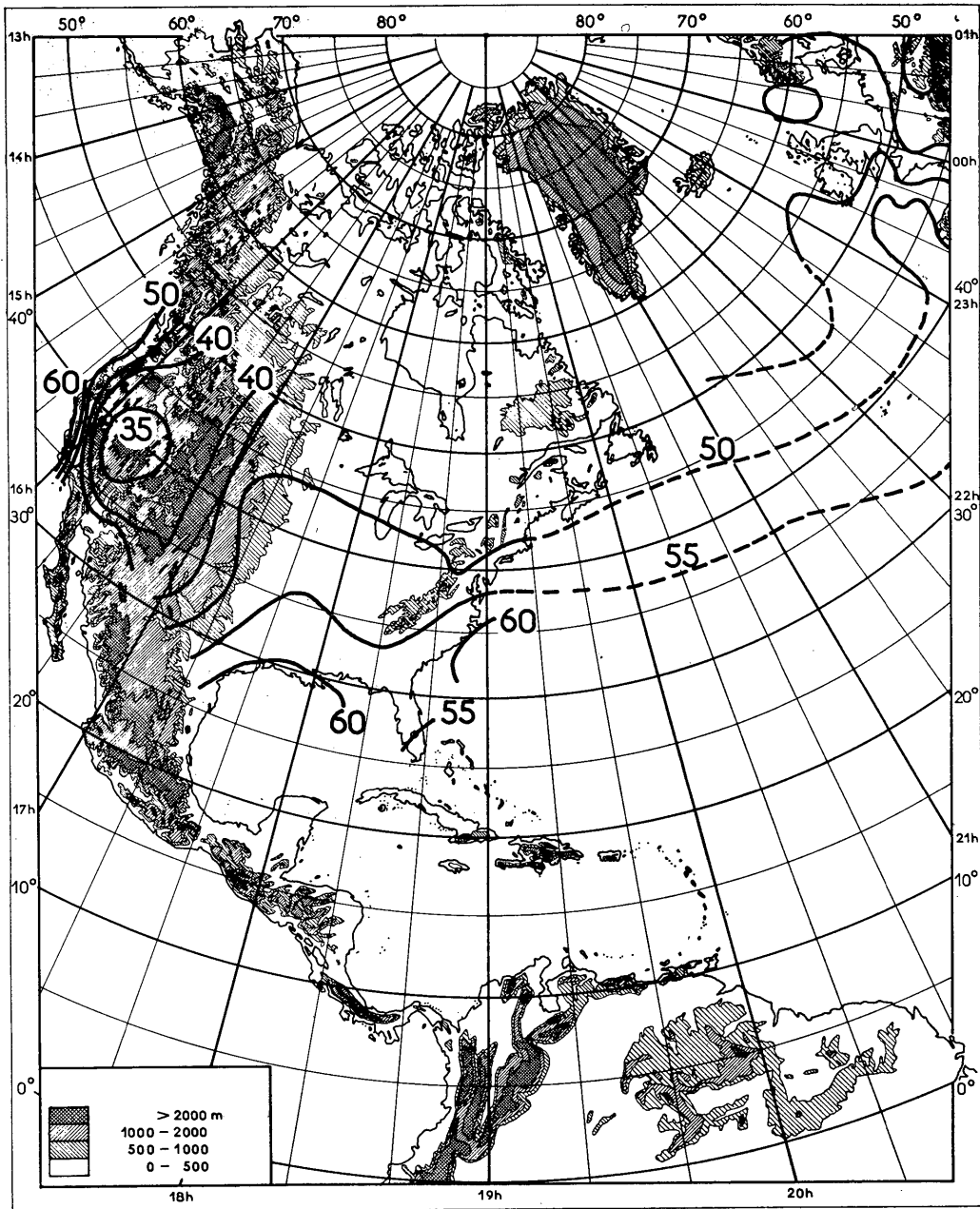


FIGURE 14

Iso — ΔN chart for the American sector for the month of August, 1500 hrs U.T.

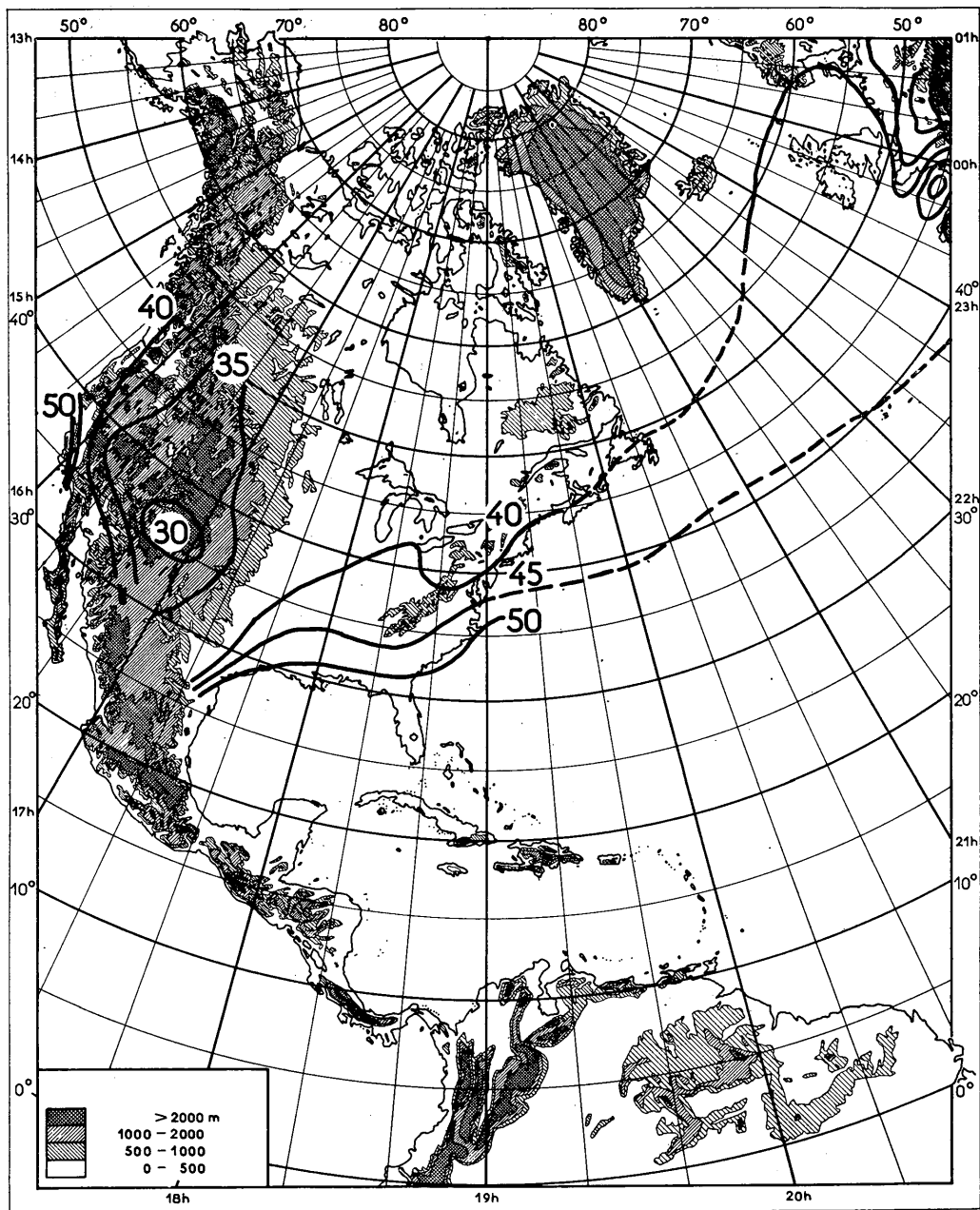


FIGURE 15

Iso — ΔN chart for the American sector for the month of November, 0300 hrs U.T.

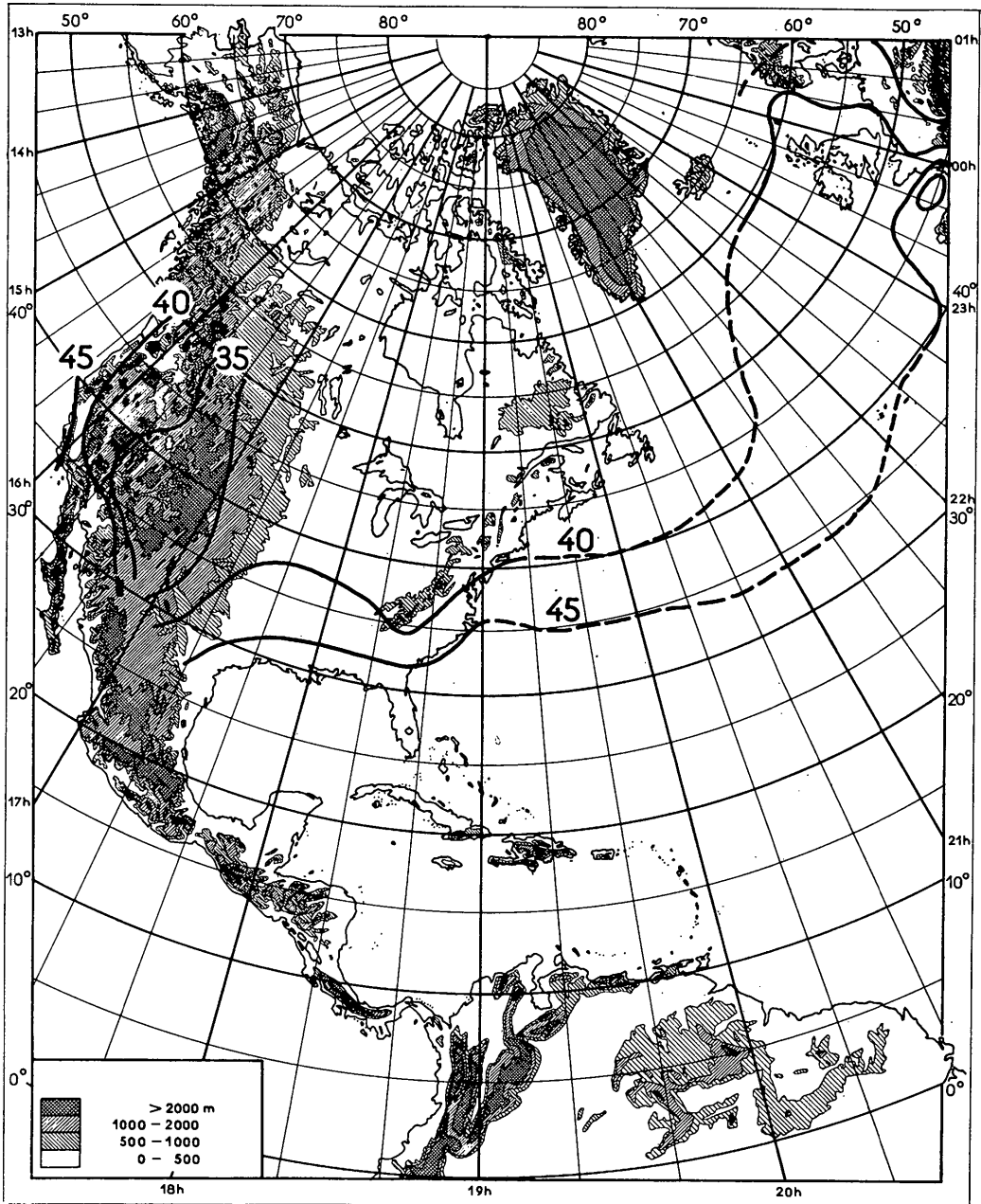


FIGURE 16

Iso — ΔN chart for the American sector for the month of November, 1500 hrs U.T.

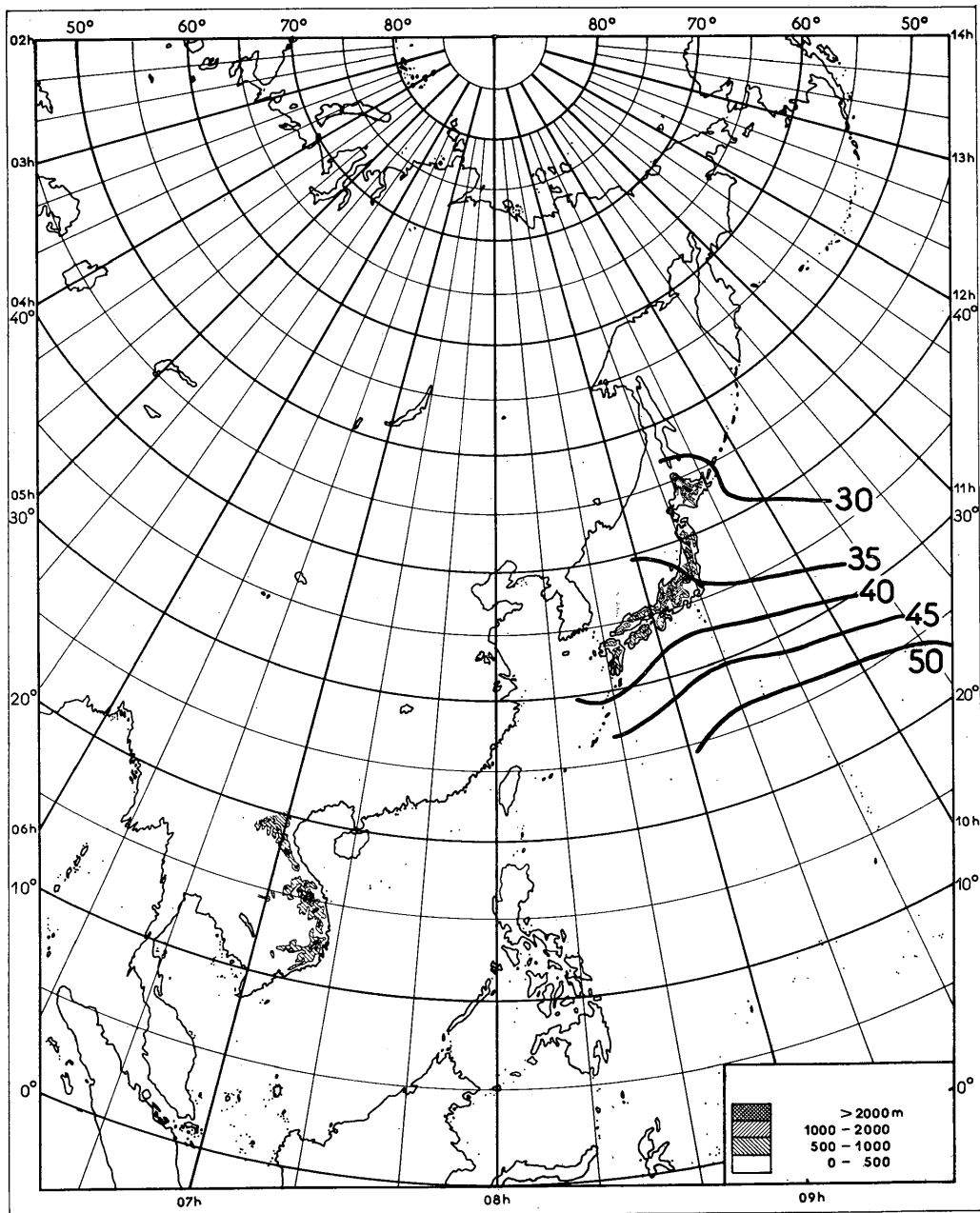


FIGURE 17

Iso — ΔN chart for the Pacific sector for the month of February, 0300 hrs U.T.

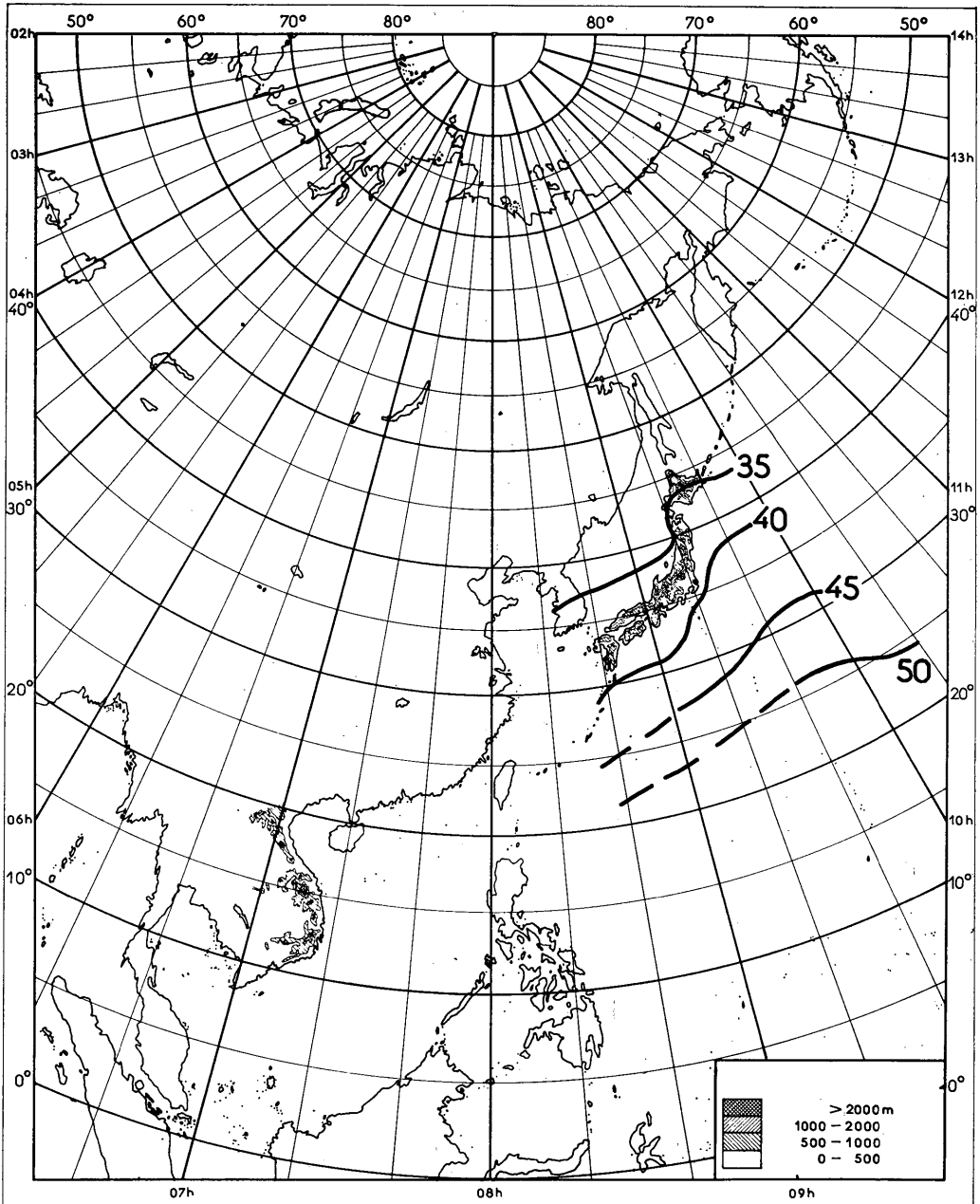


FIGURE 18

Iso — ΔN chart for the Pacific sector for the month of February, 1500 hrs U.T.

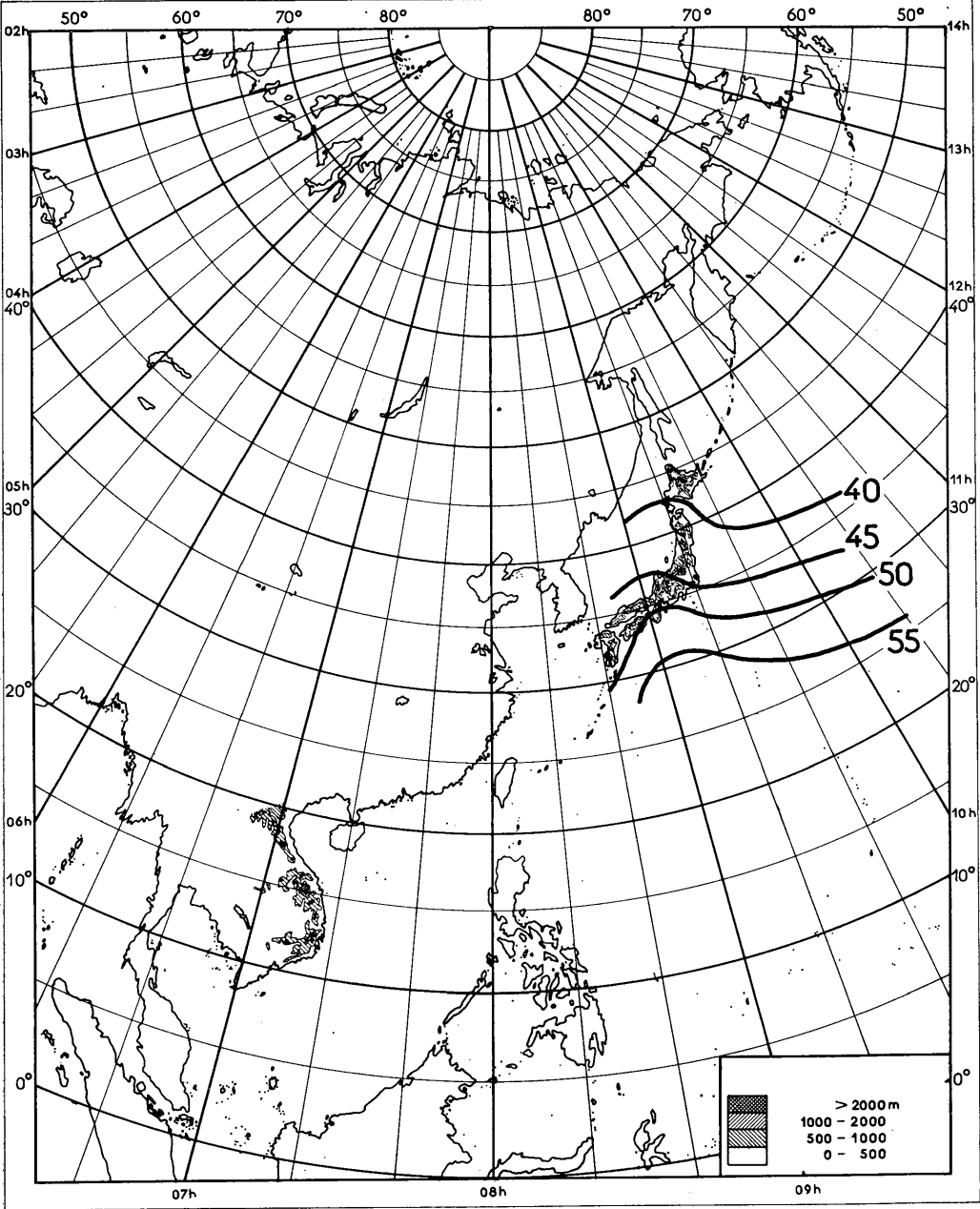


FIGURE 19

Iso — ΔN chart of the Pacific sector for the month of May, 0300 hrs U.T.

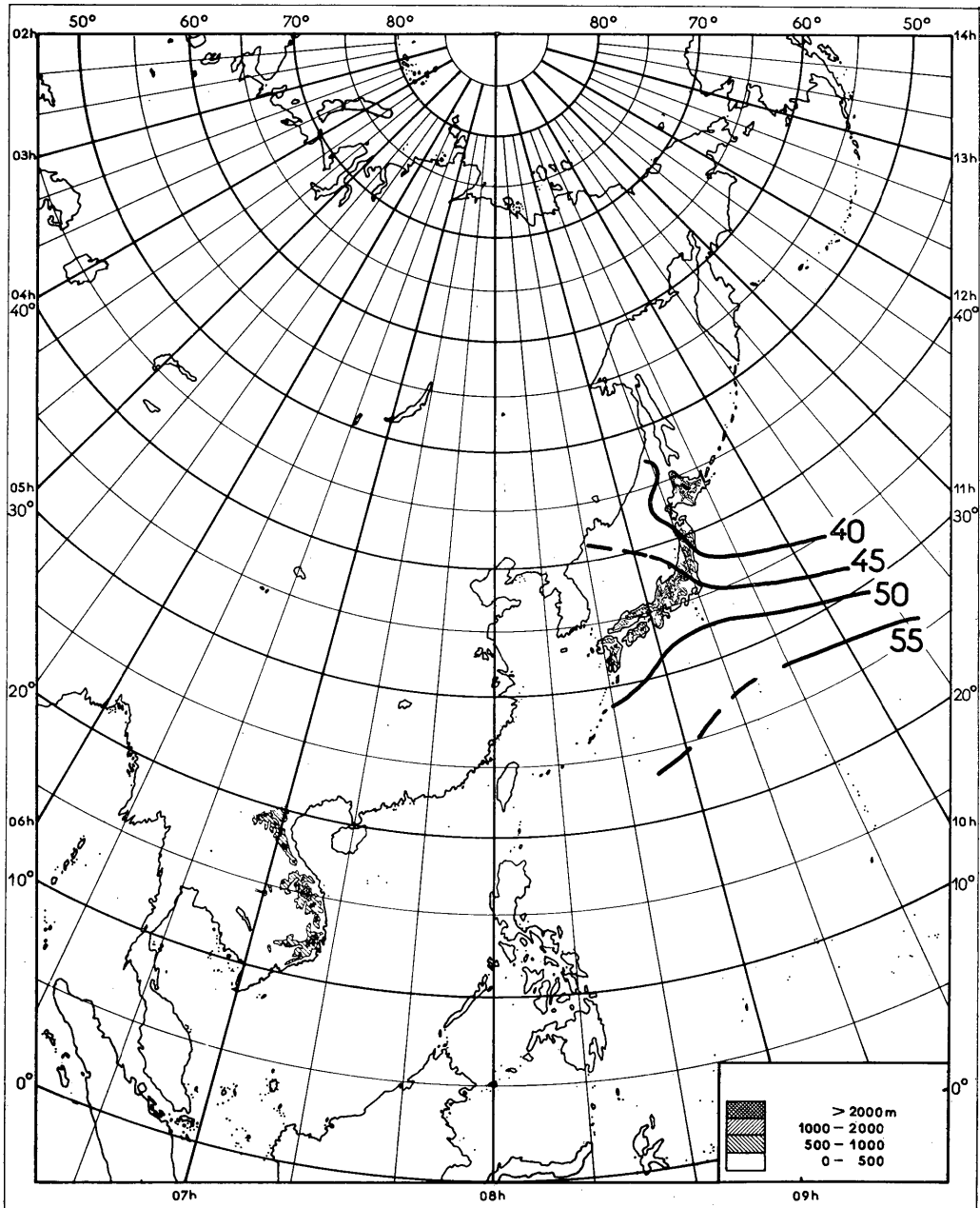


FIGURE 20

Iso — ΔN chart of the Pacific sector for the month of May, 1500 hrs U.T.

G

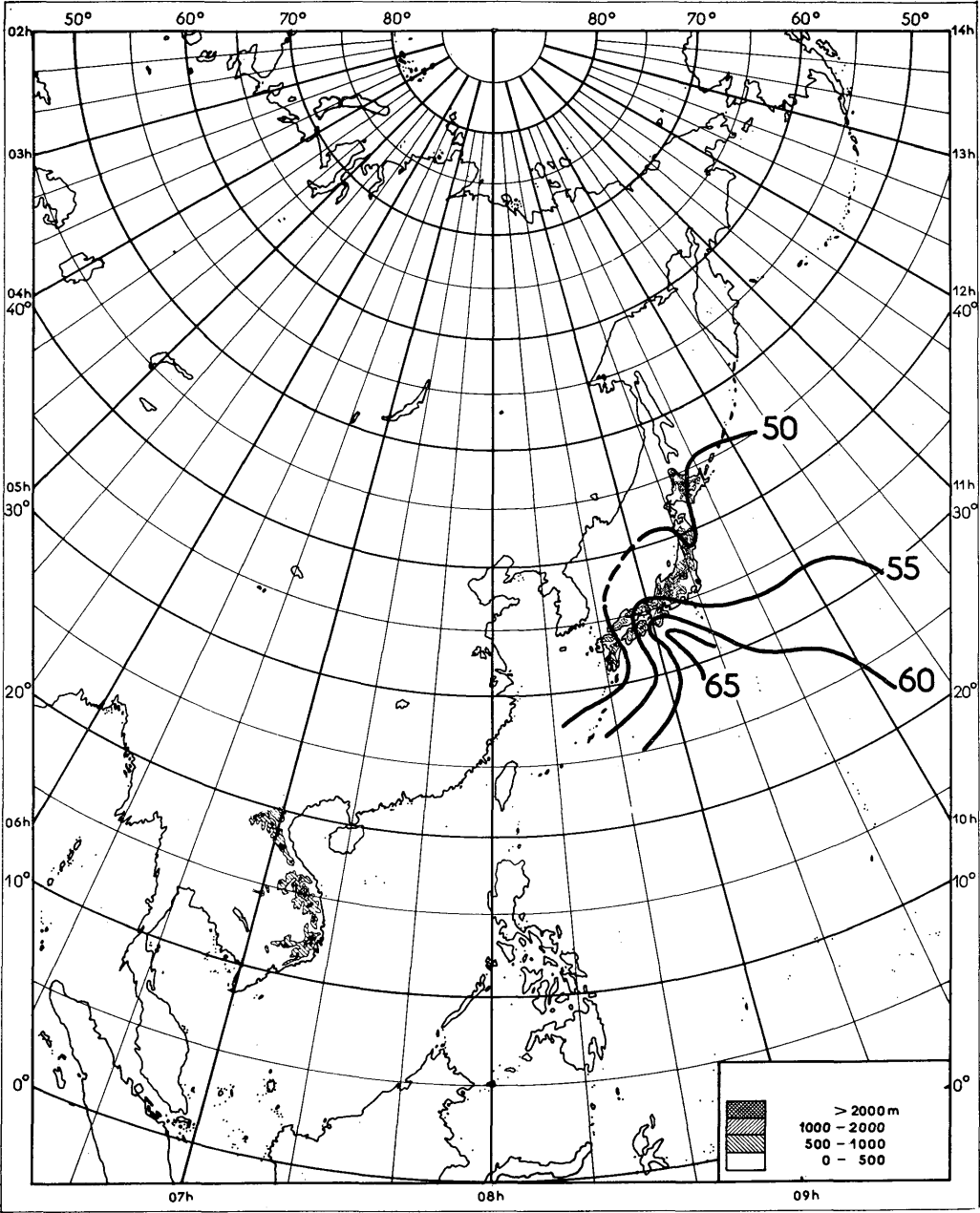


FIGURE 21

Iso — ΔN chart for the Pacific sector for the month of August, 0300 hrs U.T.

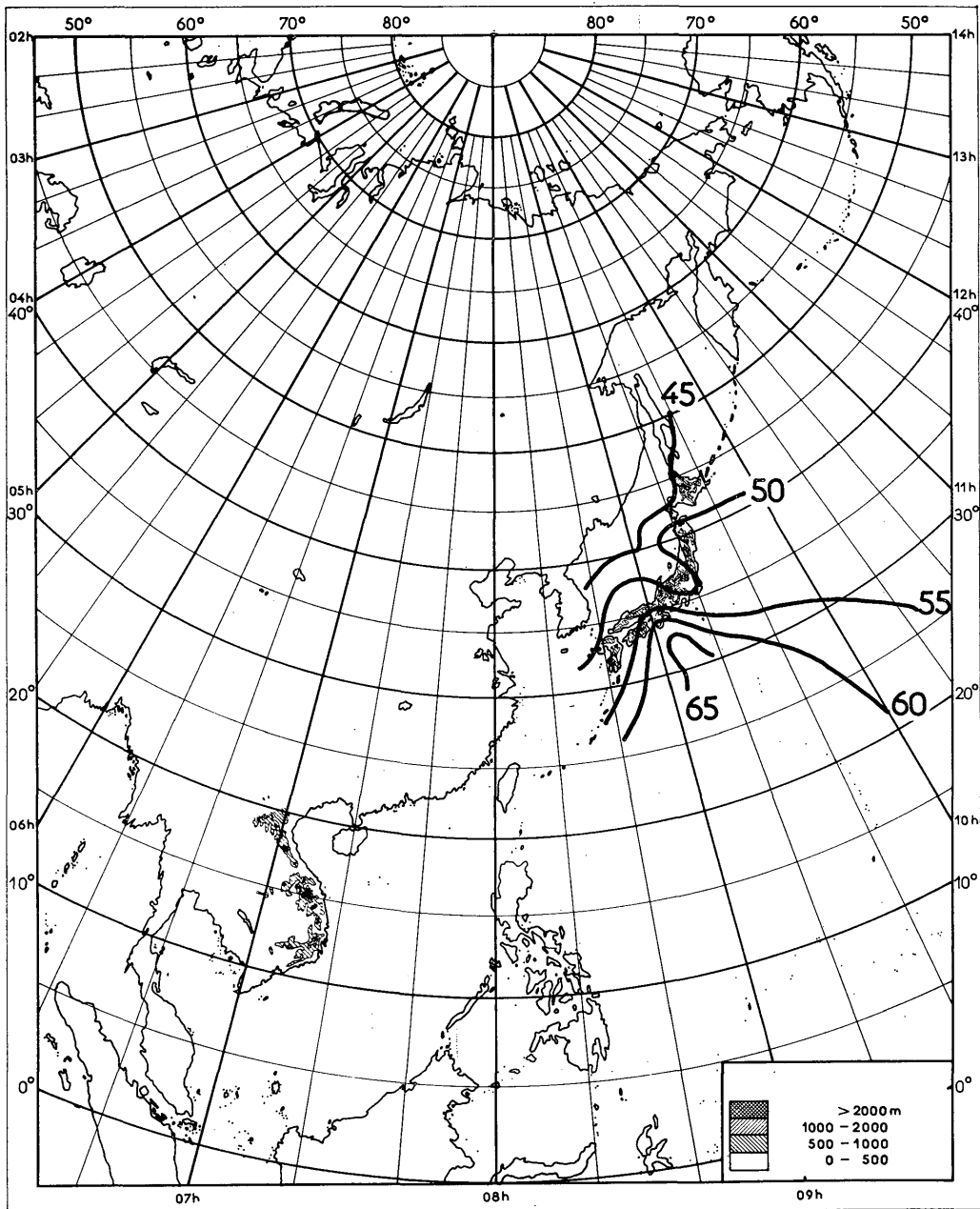


FIGURE 22

Iso — ΔN chart for the Pacific sector for the month of August, 1500 hrs U.T.

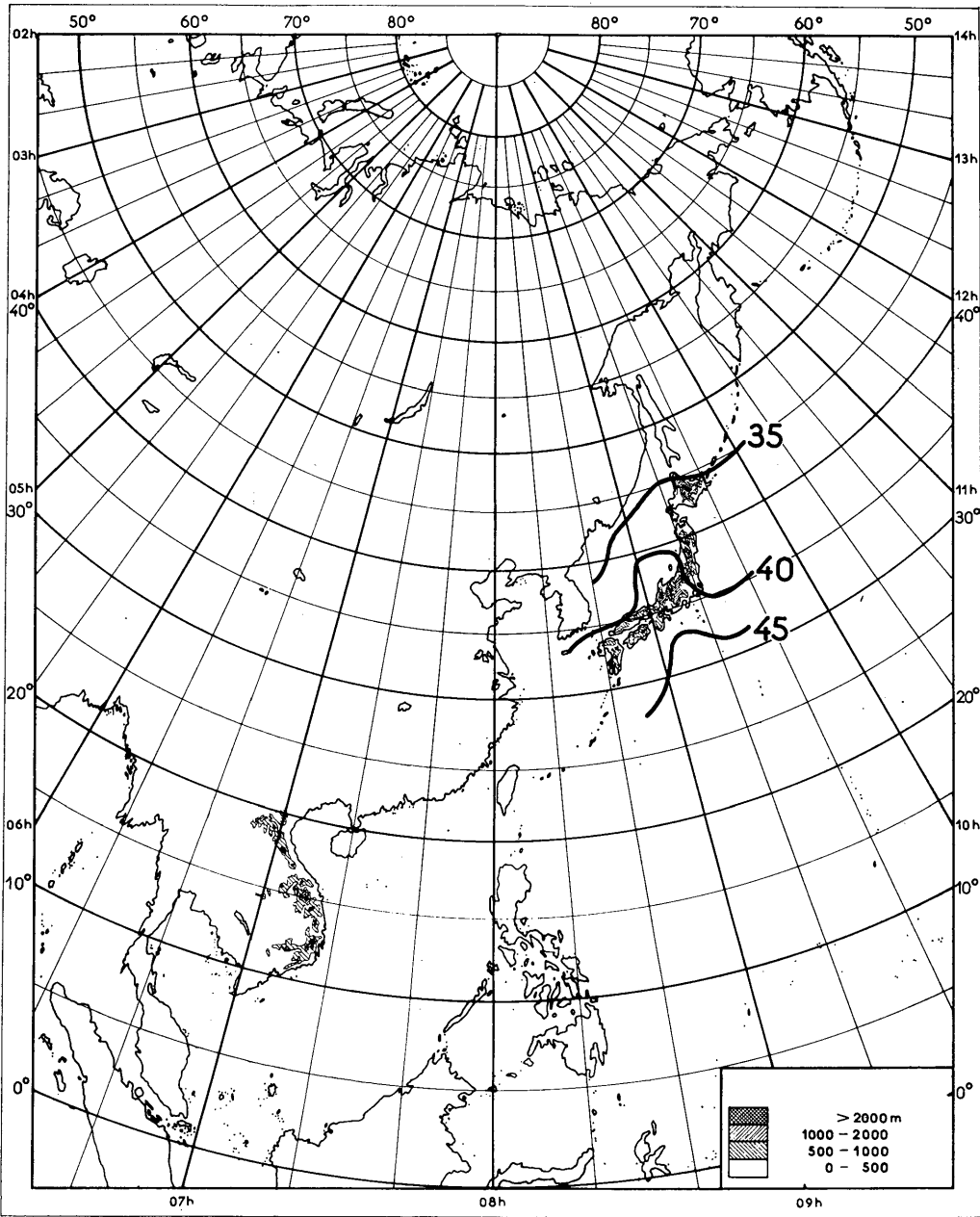


FIGURE 23

Iso —ΔN chart for the Pacific sector for the month of November, 0300 hrs U.T.

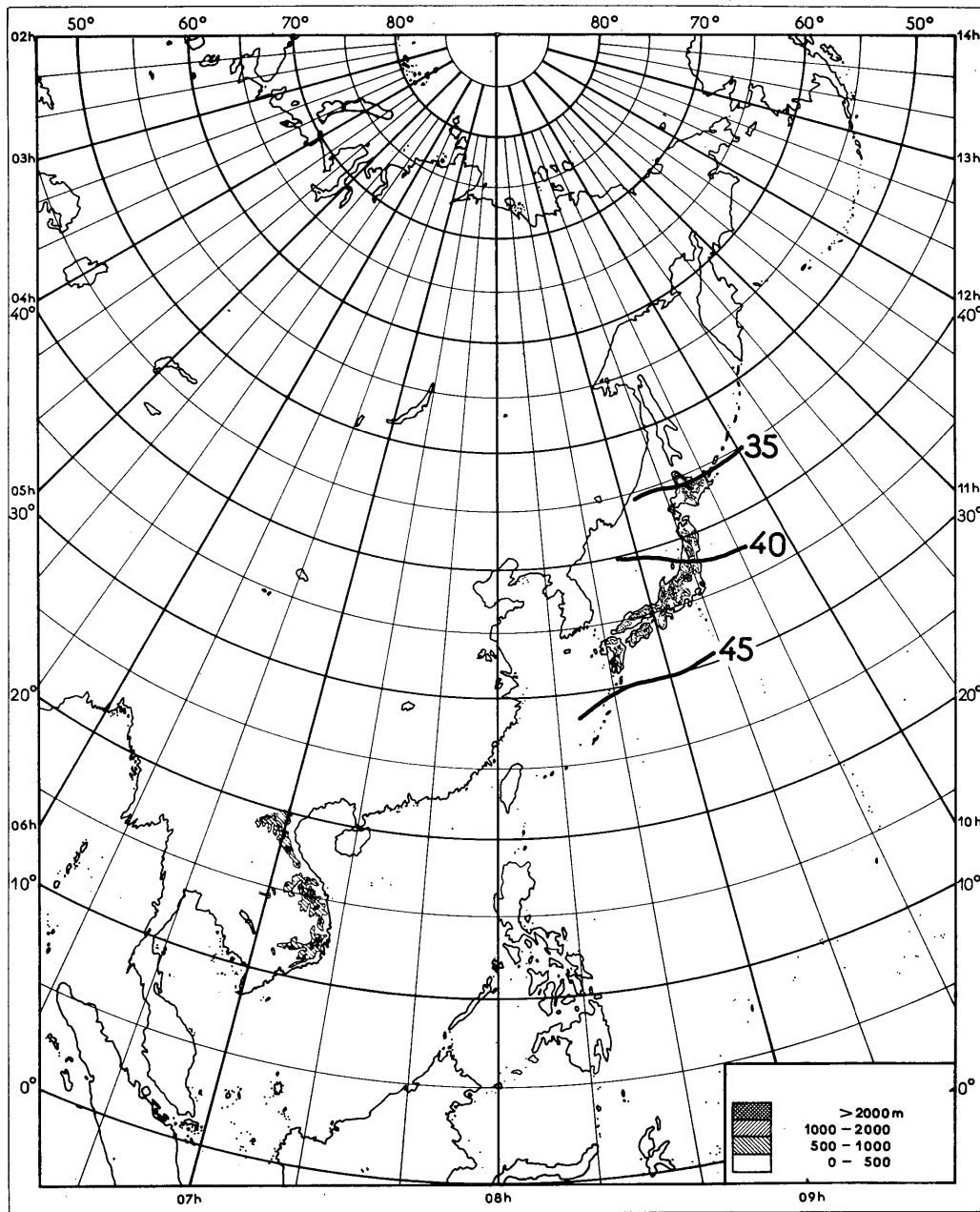


FIGURE 24

Iso — ΔN chart for the Pacific sector for the month of November, 1500 hrs U.T.

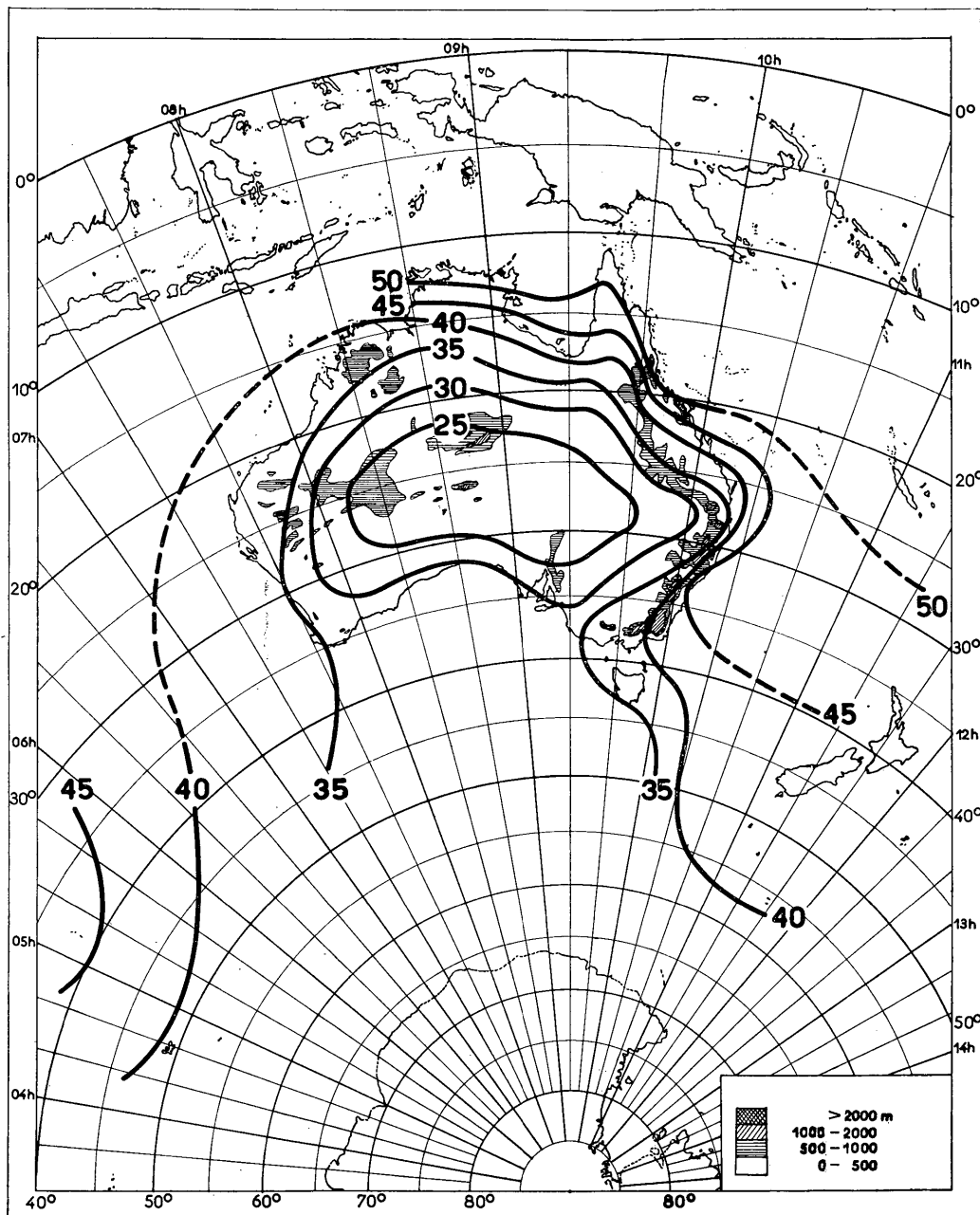


FIGURE 25

Iso — ΔN chart for the South Pacific sector for the month of February, 0400 hrs U.T.

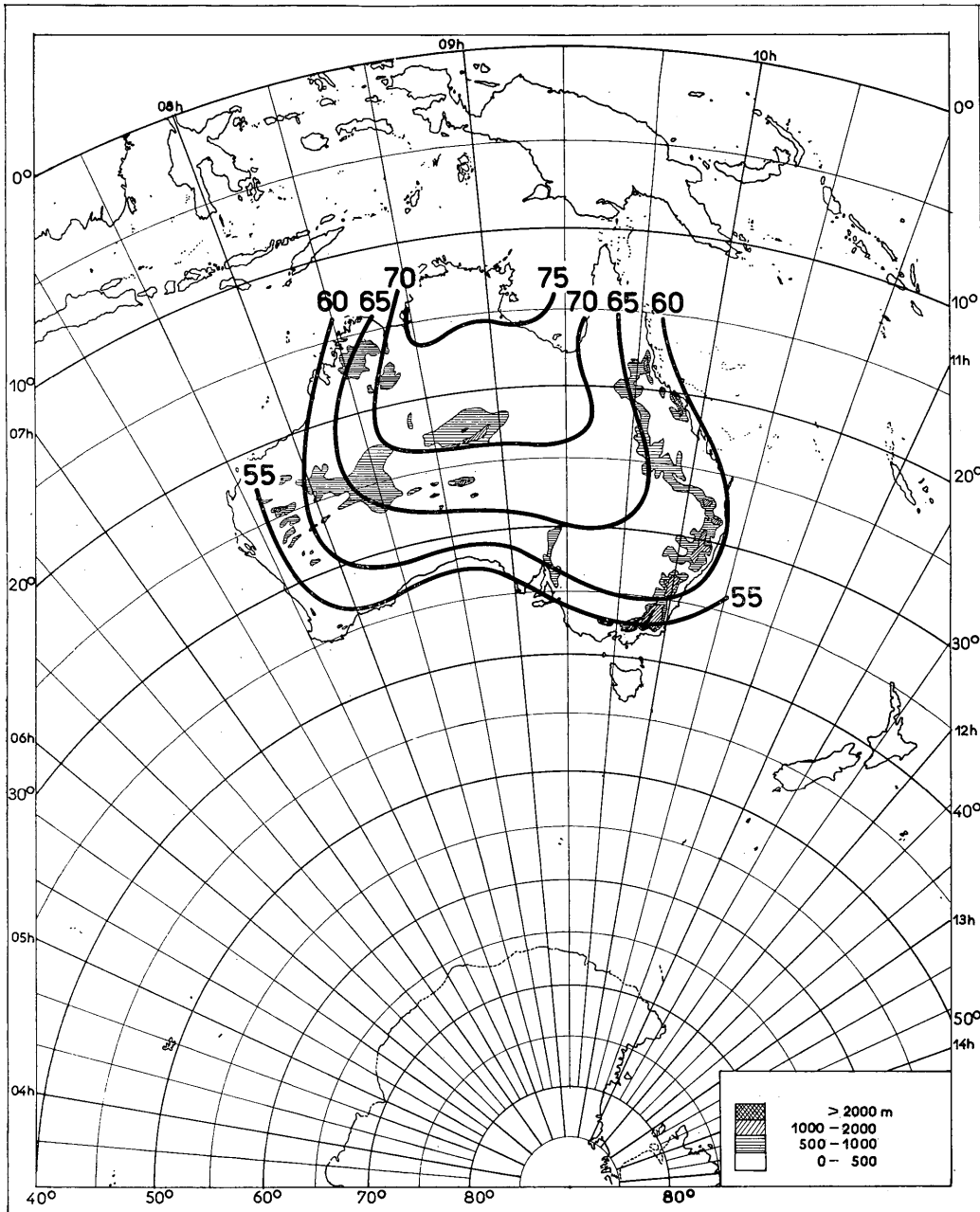


FIGURE 26

Iso — ΔN chart for the South Pacific sector for the month of February, 1600 hrs U.T.

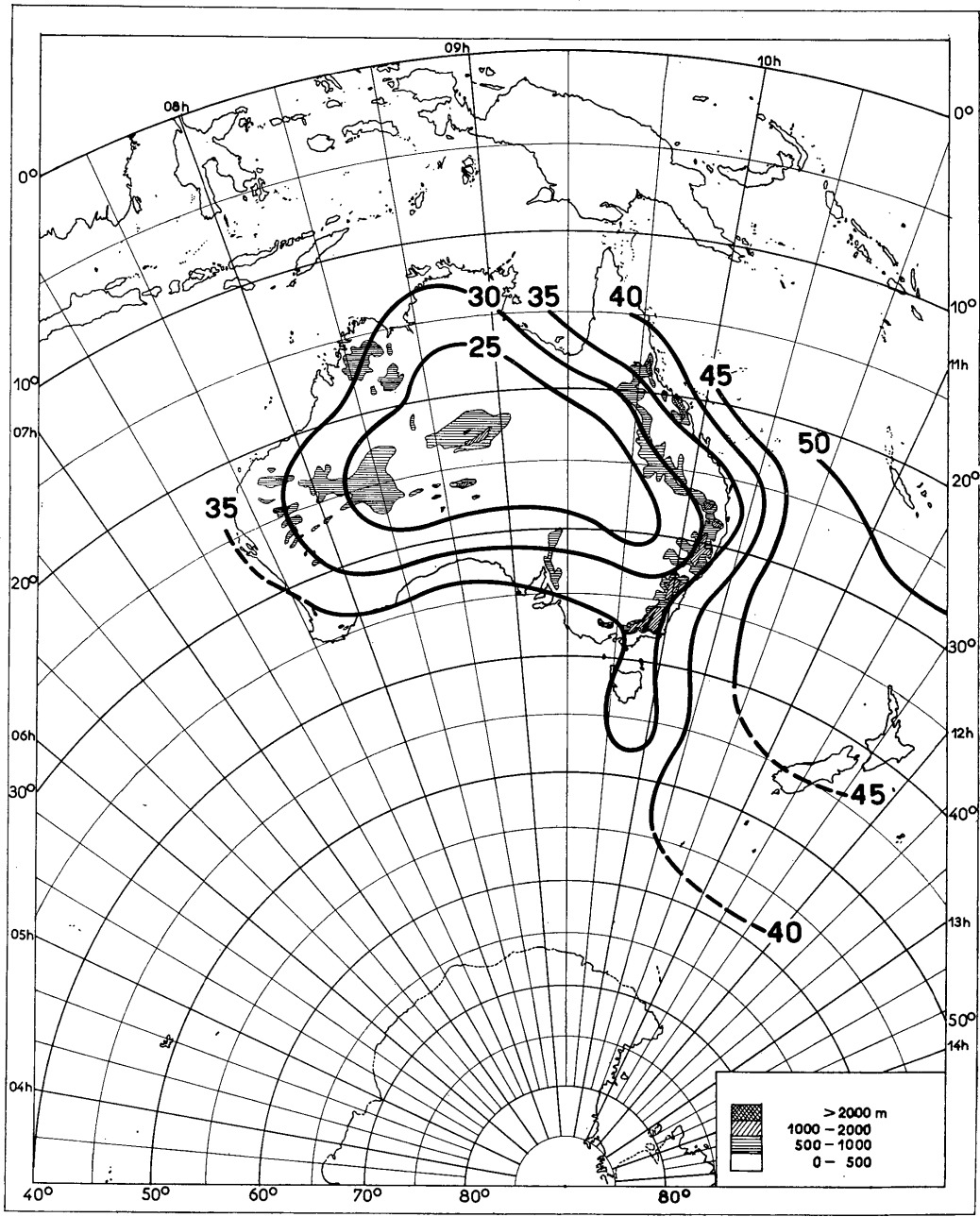


FIGURE 27

Iso — ΔN chart for the South Pacific sector for the month of May, 0400 hrs U.T.

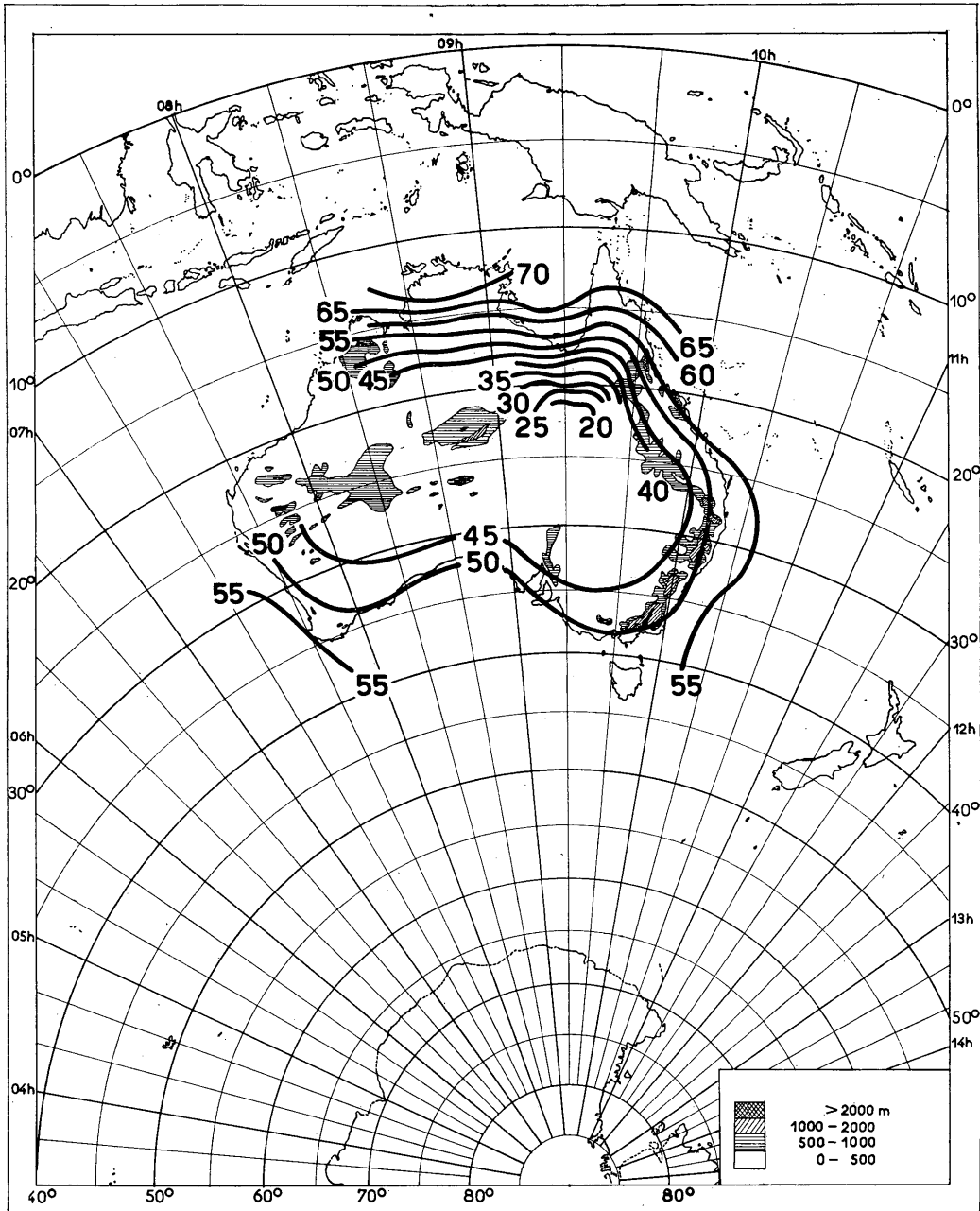


FIGURE 28

Iso —ΔN chart for the South Pacific sector for the month of May, 1600 hrs U.T.

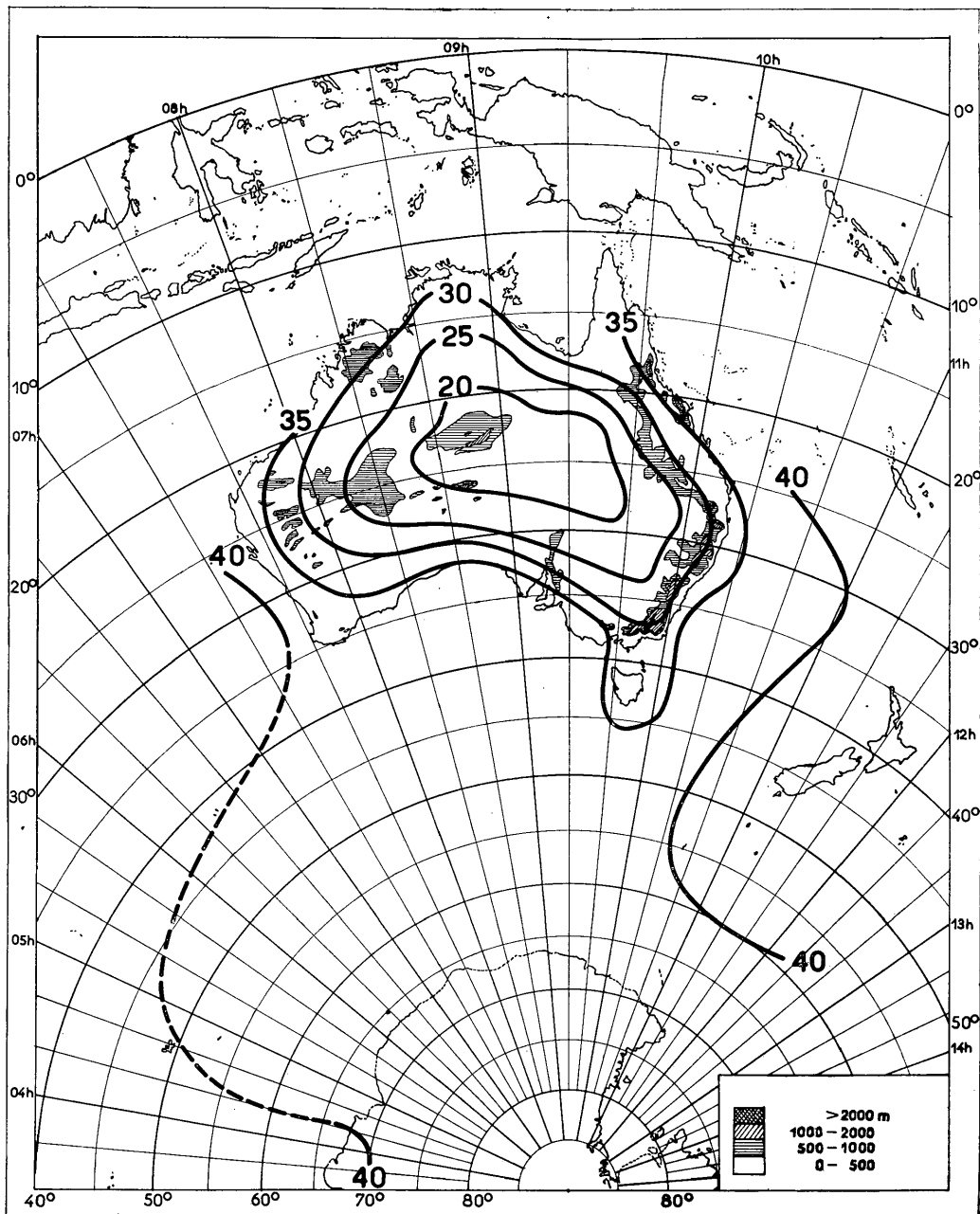


FIGURE 29

Iso — ΔN chart for the South Pacific sector for the month of August, 0400 hrs U.T.

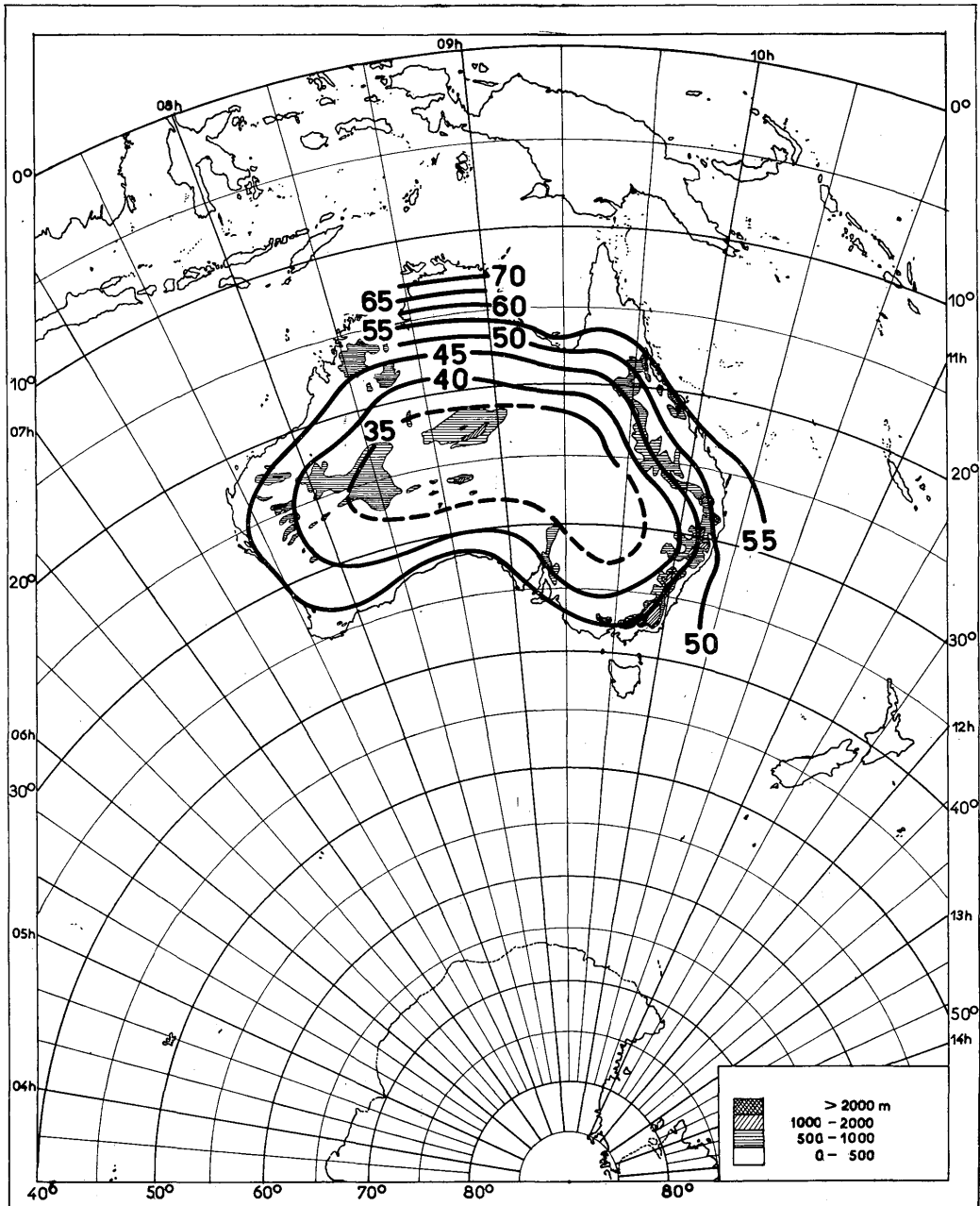


FIGURE 30

Iso — ΔN chart for the South Pacific sector for the month of August, 1600 hrs U.T.

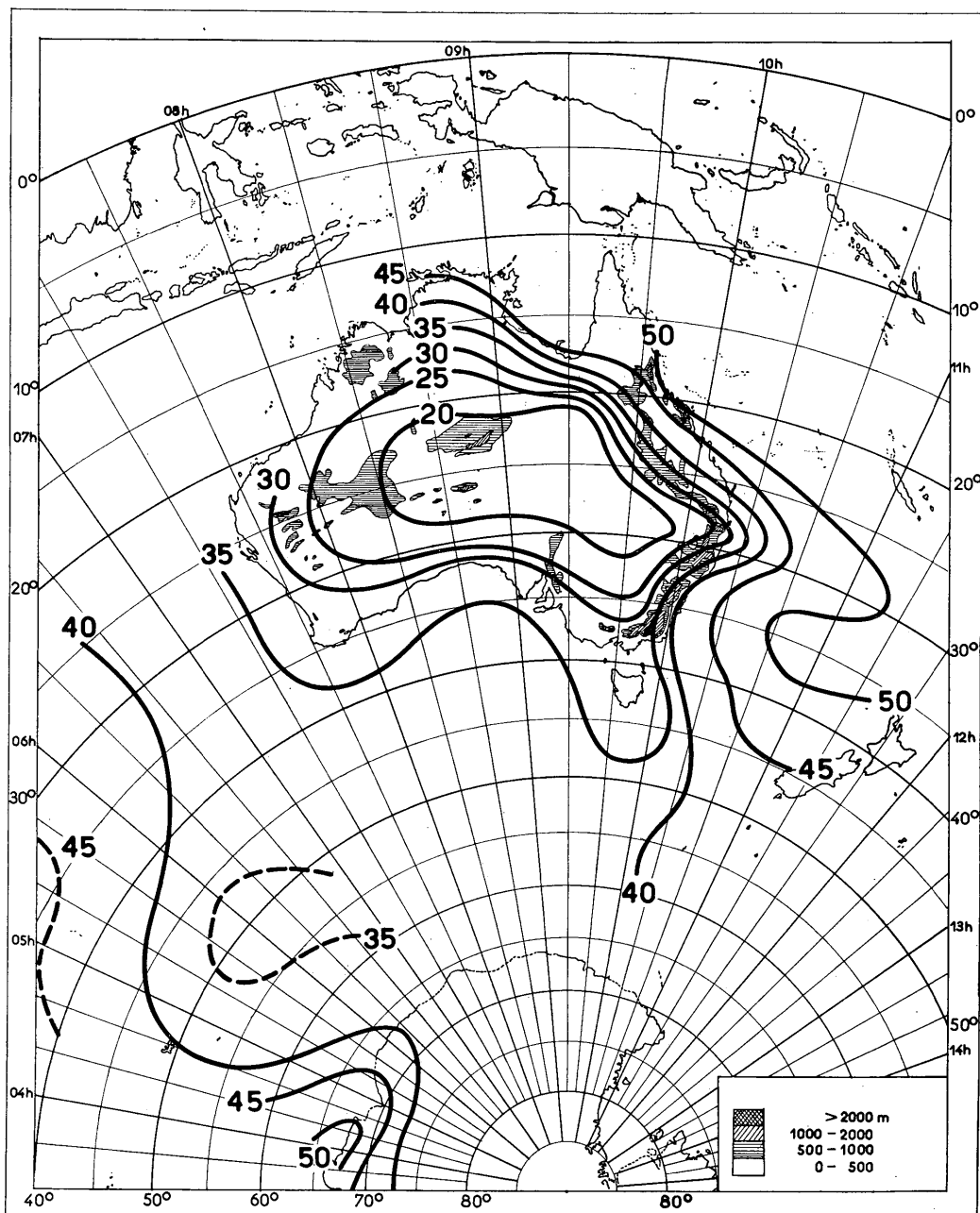


FIGURE 31

Iso —ΔN chart for the South Pacific sector for the month of November, 0400 hrs U.T.

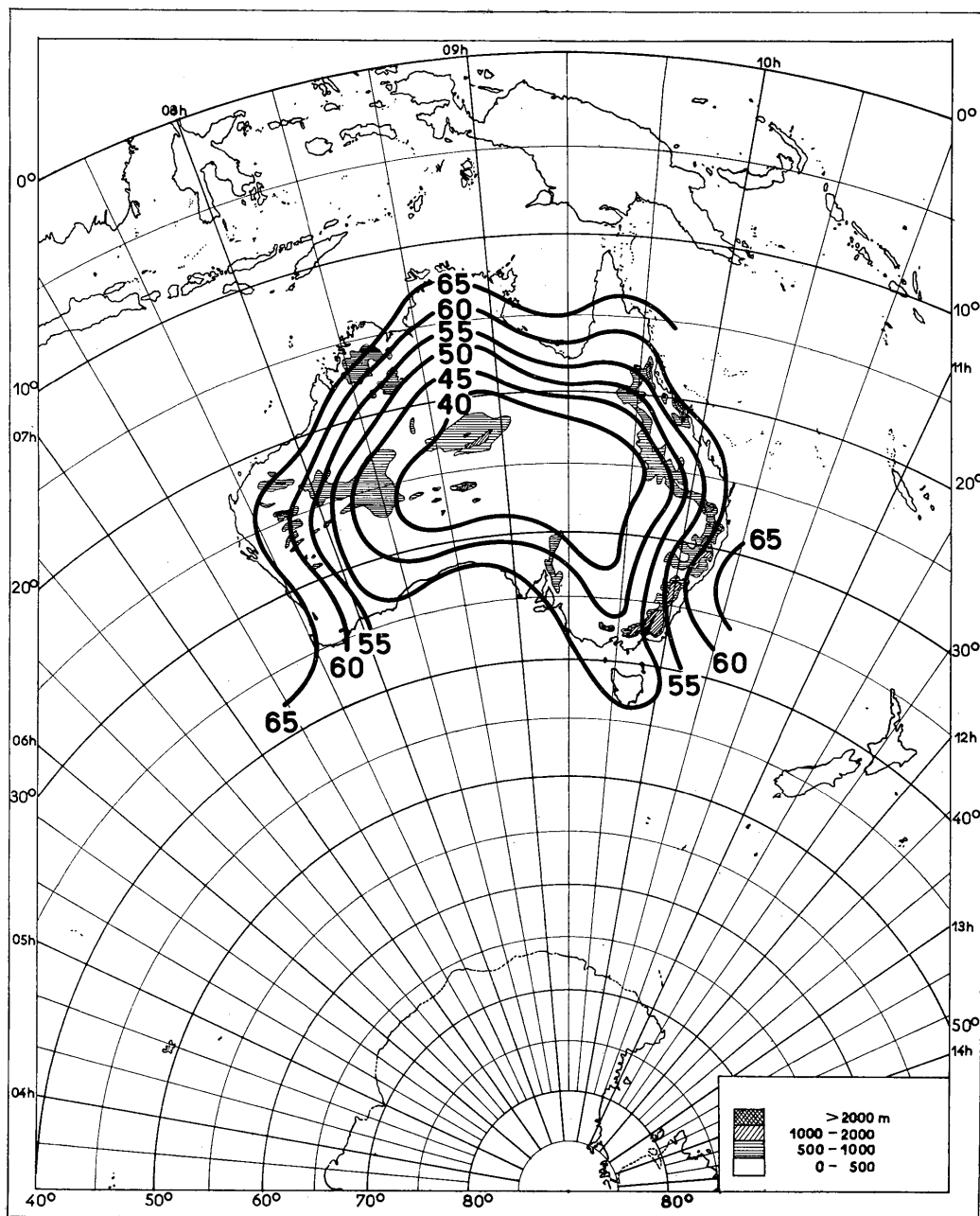


FIGURE 32

Iso — ΔN chart for the South Pacific sector for the month of November, 1600 hrs U.T.

REPORT No. 148 *

**RADIO TRANSMISSION UTILIZING INHOMOGENEITIES
IN THE TROPOSPHERE
(COMMONLY TERMED "SCATTERING")**

(Study Programme No. 139 (V))

(Los Angeles, 1959)

A number of investigations (see Bibliography) of tropospheric propagation to distances well beyond the horizon have been conducted at frequencies between 50 Mc/s and 10,000 Mc/s. At distances beyond the horizon, somewhat dependent on frequency and meteorological conditions, the radio signal is characterised by a more-or-less rapid fading and a rather small attenuation rate with distance. Fading rates of a few cycles per minute have been observed at the lower frequencies, increasing roughly as the frequency. The attenuation with distance is of the order of magnitude 0.1 db/km. Some correlations between meteorological and radio data have been noted. However, care should be exercised in extrapolating results obtained for a given location and frequency to different locations and/or frequencies.

BIBLIOGRAPHY

1. Doc. V/4 (Federal Republic of Germany) of Geneva, 1958.
2. Doc. V/11 (United Kingdom) of Geneva, 1958.
3. Doc. V/21 (Japan) of Geneva, 1958.
4. *Proceedings of the Joint Committee on Radio Meteorology*, held under the auspices of the URSI at New York University, (August 1957).
5. BREMMER, H. On the Theory of the Fading Properties of a Fluctuating Signal Imposed on a Constant Signal. *N.B.S. Circular 599*, (25 May 1959).
6. RICE, P. L., LONGLEY, A. G. and NORTON, K. A. Prediction of the Cumulative Distribution with Time of Ground Wave and Tropospheric Wave Transmission Loss. *N.B.S. Journal of Research*, Part D, (1959).
7. Particular reference is called to the *Proc. I.R.E.*, October 1955, and *Proc. I.E.E.*, **105**, Part B, (1958).
8. Reference may also be made to Documents V/3, V/55, V/63 and V/66 of Geneva, 1958 on the work carried out in connection with Recommendation No. 312 and Study Programme No. 90.
9. STARAS, H. and WHEELON, A. D. Theoretical Research on Tropospheric Scatter Propagation in the United States, (1954-1957). *Trans. P.G.A.P.-I.R.E.*, AP-7, 80-87, (January 1959).
10. Doc. 104 (U.S.S.R.) of Los Angeles, 1959.
11. Doc 131 (U.S.S.R.) of Los Angeles, 1959.

* This Report was adopted unanimously.

REPORT No. 149 *

**LONG-DISTANCE PROPAGATION OF WAVES OF 30 TO 300 Mc/s
BY WAY OF IONIZATION IN THE E AND F REGIONS OF THE IONOSPHERE**

(Question No. 7, § 3)

(Study Group No. VI)

(Geneva, 1951 — Warsaw, 1956 — Los Angeles, 1959)

1. Transmission by way of regular E-layer ionization.

A study of regularly made vertical incidence measurements indicates that it is unlikely that transmission of waves of 30 to 300 Mc/s would ever occur by way of the regular E layer.

2. Transmission by way of regular F1-layer ionization.

A study of the vertical incidence measurements indicates that it is unlikely that transmission of waves of 30 to 300 Mc/s would ever occur by way of the regular F1 layer, except near noon at maximum solar activity in tropical regions only. Since the F2 layer MUF values would, under the same conditions, exceed those for the F1 layer, this fact is of little importance. The F1 layer may have an effect on the skip distance of radio waves passing through it and then reflected by the F2 layer.

3. Transmission by way of regular F2-layer ionization.

A study has been made of the vertical-incidence measurements for a number of widely distributed ionospheric stations and, in addition, a considerable amount of observational evidence has been collected from actual transmissions. The data indicate that during certain seasons of the year at the peak of the sunspot cycle long-distance transmission by way of the regular F2 layer ionization can occur for a significant fraction of the time in temperate latitudes on waves of up to about 50 Mc/s. In the low latitudes (between geomagnetic latitudes, 20° N and 20° S), however, such transmission can occur on waves of up to 60 Mc/s, with almost regular transmission on waves of 30 to 40 Mc/s.

It is clear that, for several years around the solar maximum, intolerable long-range interference may be expected in temperate latitudes on frequencies up to about 50 Mc/s during daylight hours in the equinox and winter seasons. Similarly, for low-latitude stations, particularly in the Far East, intolerable long-range interference may be expected up to about 60 Mc/s. The lowest frequency at which such interference becomes so infrequent as to be negligible is about 60 Mc/s for stations in temperate latitudes, and about 70 Mc/s for low latitude stations. During the sunspot cycle with maximum in 1957-58 even higher frequencies were observed than for the previous maximum. However, sunspot activity during the 1957-58 maximum was the highest which has been observed since the commencement of reliable records in 1749, and this should be borne in mind when anticipating future sunspot activity. Charts of expected F2-layer interference for 1% and 10% of the time are found in Report No.109.

* This Report which replaces Report No. 54, was adopted by correspondence without reservation (see page 9)

World-wide predictions of F2-layer MUF are given in monthly charts published by the C.R.P.L. in the U.S.A., by the D.S.I.R. in the United Kingdom and by other authorities.

4. Transmission by way of sporadic-E ionization.

Because of the nature of sporadic E, implicit in its name, transmission by way of it is ordinarily confined to a single hop and is thus limited to a maximum distance of about 2300 km. Since, in the most intense form of sporadic-E ionization, the skip distance, say for 50 Mc/s is about 650 km, the transmission range is, in practice, restricted to distances between 650 and 2300 km.

Sporadic E occurs in different forms in different latitudes and it is useful to study sporadic E in terms of latitude zones. The major zones are the North and South Auroral Zones, the North and South Temperate Zones and the Equatorial Zone. The Auroral and Temperate Zones can be separated by the 15% auroral isochasm (roughly geomagnetic latitude 60°N and 60°S) whereas the demarcation line between the Equatorial Zone and the North and South Temperate Zone may be taken as the $\pm 10^\circ$ isocline of magnetic dip. In the Auroral Zones sporadic E is largely a night-time phenomenon without pronounced seasonal variation. In the Temperate Zones sporadic E concentrates strongly in the summer months and occurs most frequently between 0600 and 2359 hrs, local time, with a broad daytime maximum and frequently a secondary peak between 1700 and 2200hrs. The type of sporadic E peculiar to the Equatorial Zone is nearly transparent, and is a very regular, and a strictly daytime phenomenon with high maximum frequency.

There is also considerable variation in sporadic E inside a given zone. In the North Temperate Zone for instance, sporadic E appears to occur twice as frequently in the region around Japan as compared with United States and Europe for the same magnetic latitude (as observed at vertical incidence at 5 Mc/s). In addition, in the low latitude parts of the Temperate Zone sporadic E seems to occur twice as frequently as compared with its occurrence in the high latitude areas. Work is in progress, for example, in the U.S.A. and the U.K., on the field strength of sporadic E reflections with regard to temporal distribution and frequency dependence in these zones.

For oblique-incidence paths, particularly with wide-beam antennae, the incidence of sporadic E as predicted for the mid-point of the path may be somewhat increased by off-path reflections.

The predicted world distribution of sporadic E is indicated in world charts published monthly by C.R.P.L., in the U.S.A., and by other authorities.

5. Transmission by way of meteoric ionization.

Studies have been made in Canada, the United Kingdom, the United States, and elsewhere, of the reflections which occur from meteor trails. Report No. 157 gives a bibliography on this subject. The matter of meteor burst communication is dealt with separately as a new Study Programme No. 146 (VI).

6. Transmission by way of anomalous and irregular ionization of other kinds.

The studies indicate that there may at times occur bodies of ionization at virtual heights different from those of any of the recognized ionospheric layers. Such ionization patches may occasionally give rise to reflections of waves in the 30 to 300 Mc/s range, the principal case being that of reflection from the edges or sides of such patches which occur within or near the Auroral Zone. Such reflections may constitute a source of interference to stations working on waves in the 30 to 300 Mc/s range.

7. Table of the main causes of interference to stations working on frequencies between 30 to 300 Mc/s.

Cause of interference	Latitude zone	Period of severe interference	Approximate highest frequency with severe interference (Mc/s)	Approximate frequency above which interference is negligible (Mc/s)	Approximate range of distances affected (km)
Regular F-layer reflections	Temperate	Day, equinox-winter, solar cycle maximum	50	60	E-W paths 3000-6000 or N-S paths 3000-10,000
	Low	Afternoon to late evening, solar cycle maximum	60	70	
Sporadic-E reflections	Auroral	Night	70	90	500-2000
	Temperate	Day and evening, Summer	60	90	
	Equatorial	Day	60	90	
Reflections from meteoric ionization	All	Particularly during showers	May be important anywhere in the range		Up to 2000
Reflections from magnetic field-aligned columns of auroral ionization	Auroral	Late afternoon and night			
Scattering in the F region	Low (Western Pacific)	Evening through midnight, equinox	60	80	1000-4000



BIBLIOGRAPHY

Extensive bibliographies concerning the matter have been given in earlier C.C.I.R. documents, and are also contained in the following more recent survey papers:

1. MORGAN, M. G. A Review of VHF Ionospheric Propagation. *Proc. I.R.E.*, **41**, 582-587 (May 1953).
2. BRAY, W. J., HOPKINS, H. G., KITCHEN, F. A. and SAXTON, J. A. Review of Long-Distance Radio-Wave Propagation above 30 Mc/s. *Proc. I.E.E.*, Part B, **102**, 87-95 (January, 1955).
3. LITTLE, C. G., RAYTON, W. M. and ROOF, R. B. Review of Ionospheric Effects at VHF and UHF. *Proc. I.R.E.*, **44**, 992-1018 (August, 1956).
4. SMITH, E. K. Worldwide Occurrence of Sporadic E. *N.B.S. Circular No. 582* (March, 1957).
5. KAISER, T. R. Radio Investigations of Aurorae and Related Phenomena. *The Airglow and Aurorae*, Pergamon Press, (1959).

Developments concerning auroral reflections and F scatter bearing on the values quoted in § 7 above are contained in the following papers:

6. COLLINS, C. and FORSYTHE, P. A. A Bistatic Radio Investigation of Auroral Ionization. *J. Atmos and Terres. Phys.*, **13**, 315-345 (1959).
7. BATEMAN, R. *et al.* International Geophysical Year Observations of F-layer Scatter in the Far East. *J. Geophys. Res.* (to be published in April, 1959 issue).

REPORT No. 150 *

QUESTIONS SUBMITTED BY THE I.F.R.B.

(Study Group No. VI)

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

Although the C.C.I.R. is still not in a position to supply full answers to the three questions contained in the Annex below, progress has been made since the VIIIth Plenary Assembly and some positive measures have been taken with a view to obtaining information on which answers may eventually be based.

Study Programme No. 149 (VI) makes clear the reasons why Question (a) below cannot be fully answered at present. Moreover, some of the modifications introduced into this Study Programme, regarding methods of presentation and interpolation for instance, indicate that the problems involved in the production of MUF predictions appear now to be even more difficult than was thought. Recommendation No. 316 includes a provision intended to expedite the study of methods of presentation.

As regards Question (b) the Working Party set up by Recommendation No. 177 of Warsaw has been carrying out its tasks and reporting periodically (see Doc. No. 6 of Los Angeles, 1959) Recommendation No. 317 and Resolution No. 46 are designed to continue the work of the Group and to provide it with adequate material. Study Programmes Nos. 144 (VI) and 145 (VI) are also important in this connection.

In relation to Question (c), which is covered by Study Programme No. 142 (VI), Report No. 154 includes reference to the substantial progress which is being made in a relevant measurement programme which is being carried out by the European Broadcasting Union.

ANNEX

QUESTIONS SUBMITTED BY THE I.F.R.B. IONOSPHERIC PROPAGATION

Ionospheric propagation

Question (a)

What modification, if any, should be made to the master FOT curves used by the Mexico City High-Frequency Broadcasting Conference in order to take into account experience acquired in subsequent years ?

* This Report which replaces Report No. 56, was adopted unanimously.

Question (b)

What is the best method of calculating the field strength produced by a transmitter working on frequencies above 1500 kc/s by means of ionospheric propagation (distances up to 25 000 km) ?

Question (c)

What modification, if any, should be made to the C.C.I.R. long and medium wave night propagation curves adopted at Cairo in 1933 ? In particular they appear to need extension:

- (i) as a function of magnetic latitude,
- (ii) as a function of season,
- (iii) as a function of solar activity.

Note. — In revising and extending these curves, attention should be paid to distances less than 500 km (to allow, for example, for the evaluation of the effect of special vertical transmitting aerials designed to reduce fading in the outer part of the service area) and to distances beyond 2000 km (to allow for the evaluation of interference between regions).

REPORT No. 151 *

IONOSPHERIC SOUNDING STATIONS AFTER THE I.G.Y.

(Resolution N° 26)

(Study Group No. VI)

(Los Angeles, 1959)

1. The C.C.I.R. in Resolution No. 26 has drawn the attention of U.R.S.I. to the desirability of continuing in operation after the I.G.Y. certain of the ionospheric stations specially established or continued in operation solely for the I.G.Y. programme. The object from the C.C.I.R. viewpoint is to improve propagation forecasts.

2. From the U.R.S.I. viewpoint continued operation of certain I.G.Y. ionospheric sounding stations after the I.G.Y. would also be desirable for filling gaps in the present knowledge of ionospheric morphology and disturbances.

3. In many respects the objectives stated above may be regarded as identical.

4. The U.R.S.I. therefore recommends that as many as possible of the following stations be continued in operation preferably on a 15-minute basis for not less than one year after the next minimum of the solar cycle:

* This Report was adopted unanimously.

<i>Arctic</i>	<i>Antarctic</i>	<i>Equatorial</i>	<i>Gap Fillers</i>
Alert	South Pole	Natal	Tamanrasset
Thule	Little America	Talara	St. Johns
Svalbard	Terre Adelie	Bogota	Mexico City
Tromso	Halley Bay	La Paz	Concepción
Bukhta Tikhaya	Syowa (Showa)	Djibouti	Tahiti
Tiksi Bay	and/or	Kodaikanal	São Paulo
Providence Bay	Mawson	Bangui	Tucuman
		Davao *	Kerguelen Is.
			Macquarie Is.
			Marion Is.

5. A more detailed report has been received by C.C.I.R. from U.R.S.I., following a meeting of the U.R.S.I./I.G.Y. Committee in July 1958. This report is available and has been circulated as Doc. VI/9 of Geneva, 1958.

REPORT No. 152 **

STUDY OF METHODS FOR ESTIMATING SKY-WAVE FIELD STRENGTH ON FREQUENCIES BETWEEN THE APPROXIMATE LIMITS OF 1.5 AND 40 Mc/s

(Resolution No. 48)

(Study Group No. VI)

(Warsaw, 1956 — Los Angeles, 1959)

The Working Party of Study Group VI was set up in accordance with C.C.I.R. Recommendation No. 177, with the responsibility to advise the I.F.R.B. on the precision of the new method (R.P.U. No. 9) submitted for its use, and to study the possibility of improving and/or simplifying any method proposed for estimating sky-wave field strength between the approximate limits of 1.5 and 40 Mc/s.

In conformity with § 3 of the Recommendation, the Working Party's programme was organized by correspondence at the end of 1956 and was coordinated by the Chairman (Mr. Lépéchinsky, France).

In the period between the VIIIth and IXth Plenary Assemblies, the Working Party held three meetings, as a result of which two detailed progress reports were prepared for the Chairman of Study Group VI and the Director of the C.C.I.R.

1. At the first meeting in Geneva (December 1957), the Working Party agreed upon the following terms of reference:

- (a) *Immediate objective*: "to give the I.F.R.B. a tentative evaluation of the methods of Circular No. 462 and R.P.U. No. 9, with a view to indicating, on the basis of available measurements, the extent to which calculations based upon these methods may be trusted."

* This location is not certain. It is understood that the Philippine Government plan an I.G.Y. station at a location to the South of Manila—nearly on the magnetic equator.

** This Report was adopted unanimously.

- (b) *Overall objectives* : “ to develop a plan for the critical evaluation of existing methods, which includes additional measurements which might be feasible, paying special attention to the conditions of frequency, distance, etc., not adequately covered by existing measurements.”

After examining experimental data presented by the Federal German Republic and those contained in R.P.U. No. 9, the Working Party found for objective (a) that the results produced by both methods tend to be higher than the values measured, although the results obtained from the method of R.P.U. No. 9 are usually closer to the measured values than those obtained from the method in Circular No. 462.

Considering the overall objectives (b) the Working Party developed a detailed plan for the evaluation of the accuracy of the various methods of calculating field strength. A decision was reached:

- to carry out a series of typical calculations, using the methods of Circular No. 462, R.P.U. No. 9, and the method of Doc. 744 (Warsaw), submitted by the U.S.S.R.;
- to make comparisons of calculated field strength with actual measurements.

2. The second meeting of the Working Party was held in Geneva on 21 and 22 July 1958, immediately prior to the interim meeting of C.C.I.R. Study Group VI.

At this meeting the Working Party considered the progress of the work and made certain proposals which were adopted in the form of draft Recommendations by the interim meeting of Study Group VI. Subsequently they were adopted by the IXth Plenary Assembly at Los Angeles in April, 1959. They were: Recommendation No. 317: “ Systematic sky-wave field strength measurements on frequencies between the approximate limits of 1.5 and 40 Mc/s ” and Resolution No. 48: “ Study of sky-wave field strength on frequencies between the approximate limits of 1.5—40 Mc/s.”

The aims of these recommendations are:

- to provide the Working Party with a number of additional reliable field strength measurements, referring to widely different conditions (distances, frequencies, directions);
- to coordinate the programme of measurements by setting up a small but reliable network of key measuring stations;
- to request assistance of all Administrations, Members of the C.C.I.R.;
- to continue the Working Party under revised terms of reference, with the addition of Japan to the participating Administrations.

3. The third meeting of the Working Party was held in April 1959, in Los Angeles during the IXth Plenary Assembly of the C.C.I.R., at which time it was agreed to continue some comparisons between the various methods for typical hypothetical cases, but to concentrate more on comparing the methods with actual measurements. Discussions were held on the organization of a systematic programme of further measurements.

Progress reports will be prepared from time to time for the Chairman of Study Group VI and the Director of the C.C.I.R. Because of the large volume of work to be involved, it will be necessary for each Administration submitting a method for the calculation of field strength to be responsible for the calculations necessary to compare it with measurements or with other methods.

Contributions to the work of the Group were received from France, U.S.A., Japan, Federal German Republic, U.S.S.R., Union of South Africa, United Kingdom and the I.F.R.B.

REPORT No. 153 *

IDENTIFICATION OF PRECURSORS INDICATIVE OF SHORT-TERM VARIATIONS OF IONOSPHERIC PROPAGATION CONDITIONS

(Study Programme No. 93 (VI))

(Los Angeles, 1959)

Promising developments have occurred in studies of the joint occurrence of solar flares and enhanced solar radio noise. The results to date indicate that flares are usually not followed by storms unless accompanied by strong solar radio noise.

In recent years, especially on the occasion of the International Geophysical Year, a world-wide watch for solar flares and radio outbursts has come into being with the result that the sun is now under continual surveillance. Of importance also to the usefulness of these observations for short-term forecasting is the newly developed system for prompt distribution of these observations.

1. Usefulness and reliability of short-term forecasts.

Tests of the *usefulness* of U.K. and U.S.A. forecasts in 1953 and 1956 were carried out by the United Kingdom according to the formula

$$M = (x - ky)/S$$

where

M is a measure of the usefulness of short-term forecasts,

x is the number of storm days for which correct forecasts were issued,

y is the number of quiet days for which storm forecasts were issued, i.e., false alarms,

S is the total number of storm days,

k is an arbitrary constant depending upon how the traffic handling capacity of the system is affected by a storm and on the degree of traffic interruption which results from unnecessary action taken following the receipt of a false alarm. (United Kingdom experience suggests that $k = 0.5$ is a reasonable value).

The results indicate:

- When the 27-day recurrence cycle in ionospheric disturbances is prominent, the accuracy of the short, medium and long-term forecasts is good enough to warrant their use in making decisions on handling traffic in a radio communication system.
- During parts of the solar cycle when disturbances tend to be non-recurrent, the medium and long-term forecasts are not accurate enough for operational use. The statistical distribution of correct and incorrect forecasts is close to that which would be expected to occur by chance and this seems to imply that the precursors used are not reliable.
- The short-term (1-6 hours) forecasts are always accurate enough to justify their use. This is probably partly due to the influence of actual circuit conditions observed at the time of issue of the forecast.

* This Report was adopted by correspondence without reservation (see page 9).

The Administration of Japan reported that encouraging results are obtained with forecasts based upon an association of magnetic storms with the simultaneous occurrence of a solar flare and a solar radio noise outburst at 200 Mc/s. The following formula was developed to assess the reliability of the forecasts:

$$R = A^2/S_1S_2$$

where

A is the number of storm days correctly forecast,

S_1 is the number of storm days forecast

and

S_2 is the number of actual storm days.

Forecasts were made using two criteria, one for 60% probability, and one for 70% probability of occurrence of a magnetic storm based upon an analysis of the relationship of the occurrence of a magnetic storm to the importance and strength, respectively, of the associated flare and 200 Mc/s solar radio noise outburst. For the period May 9, to December 31, 1956, the reliability result for the 60% probability criterion was $R = 0.39$, while for the 70% criterion it was $R = 0.27$. Details of the method and results are given by K. Sinno in the Journal of the Radio Research Laboratories, Vol. IV, p. 267, 1957, and Vol. V, p. 109, 1958; H. Shibata, in the same journal, Vol. V, p. 143, 1958, gives the theory of the optimum choice of radio warning criteria.

Some relationships have been studied between Special World Intervals declared by the IGY World Warning Agency and subsequent observations of magnetic or propagation disturbances. Such relationships need to be interpreted with particular care since the declarations of Special World Intervals had different objectives and different limitations from the usual propagation disturbance forecasts. A U.S.S.R. study has shown that, while the need still continues for improved methods of forecasting disturbances, the intensified observations during the IGY Special World Intervals has provided valuable data for further study.

The Administration of France reported that prior to May 1957, only about 50% of disturbances were anticipated, but between May 1957 and March 1958, 11 out of 16 (68%) were anticipated with forecasts based upon comparisons of data on the solar chromosphere, the intensity and localization of solar radio noise, and the intensity of cosmic rays.

The Administration of Canada has shown the feasibility of an ionospheric disturbance forecasting system by observing solar noise recorded simultaneously on a wide range of radio frequencies. By noting the starting time of the noise bursts on the different frequencies, one can follow the progress of the cloud of particles through the sun's atmosphere.

2. Diurnal distribution of the times of onset of ionospheric disturbances and stability of distributed foF2.

In the U.S.S.R. statistical studies of ionospheric disturbances have been made which show that disturbances usually commence during night hours. Thus, "forbidden" intervals for storm commencements have been found for every ionospheric station in the U.S.S.R. These results have enabled short-term forecasts to be made more accurately. (See Annals of the Corpuscular Conference of the Academy of Science of the U.S.S.R., Moscow, 1957). Studies of the rapid changes of foF2 during the storms showed that the F2 layer is sufficiently stable to permit useful extrapolation of values of foF2 a few hours in advance.

ANNEX

EXTRACTS FROM A LETTER FROM THE CHAIRMAN OF U.R.S.I. COMMISSION III

Ionospheric disturbances are of two main types, associated with two known causes. Firstly there are "black-outs" caused by increased absorption in the D region. Secondly there are profound changes in the MUF caused by changes in the electron density distribution in the F region. The first type occurs in the sunlit hemisphere at all latitudes almost simultaneously with the occurrence of most bright flares near the middle of the solar disc; in high (auroral) latitudes

they may also occur both by day and by night 18–36 hours after the occurrence of such a bright flare. The former type of “black-out” is due to production of absorbing ionization in the D region by radiation from the vicinity of the flare; the latter type of “black-out” is due to ionization produced by the impact of solar corpuscles which have taken much longer to reach the earth from the sun, and which are guided to high latitudes by the geomagnetic field.

The second type of ionospheric disturbance occurs all over the earth according to a pattern which is now reasonably well known (see for example Reports of Ionospheric Research in Japan, Vol. VIII No. 1, 1954, Special Symposium on Ionospheric Storms and references there cited). The occurrence of a magnetic “Sudden commencement” heralds almost certainly the simultaneous beginning of such world-wide ionospheric disturbance. The course and magnitude of these disturbances can be forecast reasonably accurately; these depend upon latitude, season, the local time at which the (magnetic) sudden commencement occurred, and the magnitude of this sudden commencement.

Sudden commencement magnetic storms are most frequent during the rising phase of the sunspot cycle. During the decaying phase many magnetic storms (and the associated ionospheric storms) begin gradually. It is more difficult in such cases to provide adequate short-term warnings of ionospheric storms from the magnetic recordings. However, such storms have a strong tendency to recur at 27-day intervals and this method of prediction holds special promise during this phase of the sunspot cycle.

REPORT No. 154 *

RADIO PROPAGATION AT FREQUENCIES BELOW 1500 kc/s

(Study Programme No. 142 (VI))

(Los Angeles, 1959)

With reference to § 5 of Study Programme No. 142 (VI) Los Angeles, 1959, contributions based on field strength measurements have been made by the European Broadcasting Union (E.B.U.), the United States of America and Australia.

Since 1 October 1952, the E.B.U. has been carrying out a measurement campaign on ionospheric propagation on long and medium waves. Three reports on the progress made in this campaign have been submitted. Since the beginning of 1958, these studies have been carried out jointly with the I.B.O.

The first of these reports (Doc. 418, Warsaw 1956) included a comparison between the medium frequency curve according to the I.F.R.B. Technical Standard A-6 and a curve derived from the preliminary E.B.U. measurements made during the earlier years of the campaign. The two curves showed good agreement out to a distance of 2000 km, but there is an indication that beyond this distance the E.B.U. curve falls away more steeply than the I.F.R.B. curve.

The work of the E.B.U., which has continued into a period of high solar activity now includes some long distance paths and is taking account of such factors as the solar epoch, season, frequency, hour of recording and geomagnetic latitude. Although the final results of the measurements

* This Report which replaces Report No. 63, was adopted by correspondence without reservation (see page 9).

are not yet available, the work described in the second and third reports by the E.B.U. (Doc. No. VI/31 of Geneva, 1958, and Doc. No. 54 of Los Angeles, 1959) in general has confirmed the observations made in the earlier report, and gives the following indications regarding median field strengths, subject, of course, to revision when the studies are complete.

- the solar epoch has an influence which can be expressed by a single equation, independent of the path length, of the latitude and of the frequency;
- geomagnetic latitude has an influence which is independent of frequency;
- the influence of frequency is sufficient to give rise to appreciably different curves for the low frequency and for the medium frequency bands;
- it is possible that the final result of the work will be the production of curves prepared on the basis of corrected measured values, but according to a general propagation formula.

In Doc. 58, (U.S.A.) of Los Angeles, 1959, which refers to night field strengths in the frequency range 540 kc/s to 1600 kc/s based on data obtained in the U.S.A. in 1944, a year of low solar activity, curves are given for a number of geographic latitudes. If these curves are compared with the results of the E.B.U., better agreement is obtained when the comparison is made on the basis of geomagnetic latitudes than if geographic latitudes are used. The curves show a greater latitude variation than that indicated by the tentative results of the E.B.U. It is pointed out, however, in the document, that the analysis on which the U.S.A. curves are based did not take account of some minor variations with frequency and with solar activity; that part of the apparent latitude variation may be the result of seasonal difference in the solar illumination of the ionosphere at the time of the evening observations, and that such matters should be investigated before the curves are widely used outside the U.S.A.

Doc. 77 (Australia) of Warsaw 1956, gives some results on frequencies between 550 kc/s and 1220 kc/s for distances from 640 to 1300 km (400 to 820 miles). A comparison with the Federal Communications Commission (F.C.C.) curves suggests that there is agreement up to a distance of 640 km (400 miles) but that at greater distances 6 db should be added to the F.C.C. curves.

Australia presented a second interim report (Doc. VI/41 of Geneva, 1958). The following comments are based on data collected for an interval of $1\frac{1}{2}$ hours centred on the second hour after sunset.

An analysis of the recordings made from March 1953 to October 1957, shows that for distances of 640 to 1300 km (400 to 820 miles) in the north-south direction and frequencies in the range 550 kc/s—1200 kc/s, there is a common characteristic in relation to sunspot numbers in the range 0–80, but for sunspot numbers exceeding 80 there is in general little correlation between sunspot number and field strength. The mean value of the upper decile sky wave field strength varies from 0.9 to 0.5 times the inverse distance value in the sunspot number range 0–80.

Recordings of field strength for transmission over a 3600 km (2,260 mile) path in the east-west direction show a variation in the mean upper decile sky wave figure from 0.2 to 0.02 times the inverse distance value in the sunspot number range 0–100.

Significant correlations have been found between sky wave field strengths and noon values of f_oE when the monthly average sunspot number exceeds 80. These results are consistent with a reflection coefficient which varies either as a function of

$$f'/f_oE \sec \varphi \text{ or } f_oE \sec \varphi$$

The Federal Republic of Germany (Doc. VI/83 of Geneva, 1958 and Doc. 44 of Los Angeles, 1959) reported:

1. Reference § 1, 2 and 7 of Study Programme No. 142 (VI).

Vertical incidence tests made on 1430 kc/s in 1955 at the Freiburg ionospheric station (48° 6' N, 7° 48' E), which at that time belonged to SPIM, indicated the median value of the attenuation ($R = 20 \log \rho$ (db), where ρ is the vertical reflection coefficient) at night (2230 hrs, U.T. up to the end of March and 0130 hrs U.T. thereafter) to be $R_F = 1.4$ db for the F layer and $R_{Es} = 2.4$ db for the Es layer. Individual values show a large spread (extreme values: 7 db) probably due to geometrical-optical effects (in a third of the cases $R < 0$).

From vertical pulse tests on 365 kc/s carried out by the "Max Planck Institut für Aeronomie, Institut für Ionosphären-Physik" at Tsumeb (19° 14' S, 17° 43' W) an average R -value of 17 db ($\rho \approx 14\%$) was found for the period September 1957 to March 1958 (time of measurements about 2 hours after sunset). The reflections encountered on this frequency were exclusively those from the E region (90–115 km). The higher the height of reflection the greater was the attenuation. While F and Es—reflections occurred on 1070 kc/s, selected E region echoes gave rise to an average value of $R = 6.1$ db for the same period.

2. Reference § 3 of Study Programme No. 142 (VI).

From the 707 ionograms made in August 1957, it is difficult to identify the numerous echoes, but they can be sub-divided according to distribution and variation with time of the ionization below the F region into three groups:

- one or several Es layers, at a height of about 100 km screen the entire overhead region against electro-magnetic waves (occurrence 45.7%);
- intermediate reflections occur in an ionized region at heights between 130 and 220 km. Near the intermediate layer delays of varying magnitude are found. In addition, a more or less transparent Es layer may be found (occurrence 7%);
- no echoes from the intermediate layer are observed between heights of 130 km and the F-layer. As in the preceding group, Es echoes may or may not occur (occurrence 47.3%).

It is expected that further evaluation of the test results will produce information on the following:

- decrease of Es ionization at night,
- effects at sunrise and sunset,
- correlation of intermediate layer and magnetic character figures,
- disturbances of the ionization distribution that travel from the F layer into the intermediate layer,
- extraordinary component (occasionally observed) that obeys the reflection condition

$$f_o^2 = f^2 + f \cdot f_H \quad (\text{see references})$$

The United States (Doc. VI/8 of Geneva 1958) reports considerable progress on the basic issues covered in this programme.

Bibliography.

1. WATTS, J. M. and BROWN, J. N. *J. Geophys. Res.*, **59**, 71-86 (1954).
2. PIGGOTT, W. R. *J. Atmosph. Terr. Phys.*, **7**, 341-342 (1955).
3. PFEIFFER, H. R. and MITRA, A. P. *J. Atmosph. Terr. Phys.*, **6**, 297 (1955).
4. PHILLIPS, G. J. *B.B.C. Quarterly*, **8**, No. 1, 40-50 (1953).

3. Vertical incidence.

Several years of data (equivalent height, time of day, change of phase versus time of day, ionospheric absorption and sky-wave polarization) have been studied at Pennsylvania State University. Other studies include:

- electron density-height profiles in the lower E and D regions;
- low frequency h'F records covering 50-800 kc/s;
- phase fluctuations on 75 kc/s;
- theoretical and experimental aspects of low frequency sunrise effects and night-time E layers;
- an experimental programme is being initiated utilizing rockets to determine the electron density-height profiles in the D and lower E regions.

Bibliography.

- PARKINSON, R. W. The Fading Periods of the E-Region Coupling Echo at 150 kc/s. *J.A.T.P.*, **8**, No. 3, 158-162, (March 1956).
- FERRARO, A. J., GIBBONS, J. J., HOUTSON, R. E., ROSS, W. J. and SCHMERLING, E. R. 75 kc/s Pulse Normal Incidence Ionospheric Sounding. *Proc. of Symposium on the Propagation of VLF Radio Waves, N.S.B.*, **2**, 13.1-13.7, (January 1957).
- BOWHILL, S. A. Ionospheric Irregularities Causing Random Fading of Very Low Frequencies. *Proc. of Symposium on the Propagation of VLF Radio Waves, N.B.S.*, **3**, 28.1-28.10, (January 1957).
- WAYNICK, A. H. The Present State of Knowledge Concerning the Lower Ionosphere. *Proc. of Symposium on the Propagation of VLF Radio Waves, N.B.S.*, **3**, 34.1, (January 1957).
- MITRA, A. P. Night-time Ionization in the Lower Ionosphere — I. Recombination Processes. *J.A.T.P.*, **10**, 140-152, (March 1957).
- MITRA, A. P. Night-time Ionization in the Lower Ionosphere — II. Distribution of Electrons and Positive and Negative Ions. *J.A.T.P.*, **10**, (March 1957).
- WAYNICK, A. H. The Present State of Knowledge Concerning the Lower Ionosphere. *P.I.R.E.*, **46**, 741-749, (1958).
- BOWHILL, S. A. Ionospheric Irregularities Causing Random Fading of Very Low Frequency. *J.A.T.P.*, **11**, 91-101, (1958).
- GIBBONS, J. J. and RAO, B. R. The Calculation of Group Indices and Group Heights at Low Frequencies. *J.A.T.P.*, **11**, 151-162, (1958).

The Central Radio Propagation Laboratory of the National Bureau of Standards has reported vertical incidence soundings (50-2000 kc/s) since 1953.

Data is available on:

- E-reflection frequencies,
- lowest observed frequencies from the F-layer ordinary ray and
- height of E-region echoes.

(WATTS, J. M. and BROWN, J. N. Some Results of Sweep-Frequency Investigation in the Low Frequency Band, *Journal of Geophysical Research*, Vol. 59, March (1954)).

The more recent results lead to a better understanding of traces from the intermediate layer, which is complicated by a type of retardation not seen at higher frequencies.

4. VLF propagation studies using sferics.

The Central Radio Propagation Laboratory is conducting a programme utilizing sferics as a signal source. Recordings consist of the vertical electric field together with time marks for identification of individual sferics. From the amplitude spectra, the attenuation properties of

the propagation medium are determined as a function of frequency, distance, duration and time of day. Analysis is being made to determine attenuation rates for day and night conditions as well as for land and sea paths.

5. Transmission loss calculations for propagation at VLF.

The transmission loss of VLF waves at great distances are characterized by very low attenuation since the sky waves are almost totally reflected from the lower edge of the ionosphere. Experimental data indicates the reflecting height varies consistently from near 70 km in the day time to about 90 km at night. Using the mode theory of VLF propagation extensive transmission loss and phase curves have been prepared for the frequency range 10-20 kc/s. The calculated results compare favourably with experimental data taken at 16.6 kc/s over the Pacific Ocean.

Bibliography.

1. WAIT, J. R. *National Bureau of Standards Report No. 5557*, (February 22, 1958).
2. (See papers by PIERCE, J. A., WAYNICK, A. H., BUDDEN, K. G., YABROFF, I. W., WATT, A. D., PIERCE E. T. and WAIT, J. R.) *VLF issue of the Proceedings of the Institute of Radio Engineers*. 45, No. 6, (June 1957).
3. WAIT, J. R. and MURPHY, A. Multiple Reflections between the Earth and the Ionosphere in VLF Propagation. *Geofisica Pura e Applicata*, 35, 61-72, (1956).
4. NORTON, K. A. Transmission Loss in Radio-propagation. *National Bureau of Standards. Report 5092*, II, (July 25, 1957).

6. Whistler mode of propagation.

Experimental and theoretical studies have been conducted in the United States by Stanford University, Dartmouth College, Naval Research Laboratory and the Central Radio Propagation Laboratory to investigate the whistler mode of propagation of VLF radio waves over extreme distances. Data have been collected and correlated in various parts of the world which indicate that many whistlers can be identified at each of two conjugate locations. The major portion of the work has been devoted to whistlers generated naturally by lightning discharges and which travel to their approximate magnetically conjugate locations by following lines of the earth's magnetic field. Thus, the path may extend to several earth's radii.

Recently, Stanford University reported the results of artificial propagation by the whistlers mode. The test involved transmission from radio station NSS, Annapolis, Maryland and reception near Cape Horn, South America. Even though the receiving station was about 1700 km (1000 miles) from the magnetic conjugate point, important results were obtained relating to multipath propagation, split echoes and fading. Poor correlation was observed between reception of whistlers and strong NSS whistler-mode signals.

REPORT No. 155 *

**STUDY OF SKY-WAVE PROPAGATION ON FREQUENCIES
BETWEEN THE APPROXIMATE LIMITS OF 1.5 AND 40 Mc/s
FOR THE ESTIMATION OF FIELD STRENGTH**

(Study Programme No. 144 (VI))

(Los Angeles, 1959)

The following contributions were received in response to Study Programme No. 99 (which has been replaced by Study Programmes Nos. 144 (VI) and 145 (VI)).

The method described by the United Kingdom in Doc. VI/38 of Geneva, 1958. The method is an extension of the CRPL method and is published in the Radio Research Special Report No. 27 **. The curves in Circular 462 for the absorption index k have been replaced by new ones, resulting from recent measurements of absorption in tropical and medium latitudes. Allowance for finite relaxation time of the absorbing layers and for more absorption after sunset is made. The method is developed for distances up to 4000 km between latitudes 50° N and 50° S but can also be applied in combination with the CRPL procedure to greater distances.

The method described by the German Administration in Doc. VI/30 of Geneva, 1958, (published in *Nachrichtentechnische Zeitschrift*, 11, No. 10, (1958)). By comparing the frequency dependence of field strength measurements made over a particular path, a two-term approximation was derived to include not only non-deviative but deviative absorption (and probably some effects due to scattering) to a reasonable degree. For practical applications, the two parameters necessary for the determination of the variation of field strength with frequency are f_L (called the LUF which is the lower frequency at which the field strength is 1 $\mu\text{V/m}$) and f_M (the so-called scatter-MUF defined as the upper frequency at which the field strength is 1 $\mu\text{V/m}$). Prepared charts give the field strength directly. Since the reliability of this method has only been observed between North America, South America and Europe, further investigation is necessary. For predictions to other areas of the earth, estimates of the parameters f_L and f_M may be obtained by existing methods of predicting field strengths.

Japanese investigations in Doc. VI/90 Of Geneva, 1958, include studies of large systematic path deviations which result from re-radiation from large land masses lying outside the normal great-circle path. It is possible that this may influence future considerations of the protection which may be realized between different radio circuits unless greater side-lobe suppression is achieved. Information is also given concerning propagation involving ground scatter by way of Es clouds appearing near the great-circle path. Pulse and direction-finder measurements were made to support the above findings. Prediction of operational MUF for radio circuits considering the great-circle paths and the deviated paths was explained in Warsaw Doc. No. 91.

The Italian Administration in Doc. VI/63 of Geneva, 1958, presented charts for reliability computations of both the LUF and MUF on a statistical basis. Further analysis is deemed

* This Report was adopted unanimously.

** Published by H. M. Stationery Office, London, 1959.

necessary to determine more accurately the influence of statistical distributions of such basic quantities as LUF and MUF upon the final field strength estimation for a radio path.

The Administration of India in Doc. No. 90 of Los Angeles, 1959, carried out investigations during the last few years to determine some of the factors necessary in the evaluation of the sky-wave field strength measurements. It was observed that the measured values of field strength in this tropical region do not agree with the values calculated by two of the currently available methods (i.e. CRPL and SPIM). Moreover, some solar control of the night-time field strength has been observed and the two methods do not consider this factor. These investigations are being continued and the tentative conclusions at this time are:

- the average value of diurnal variation can be expressed by $|\log \rho| = \text{Const.} (\cos \chi)^n$ where the average value of n is 0.62;
- the sunspot variation factor is 0.0017 (this is significantly lower than those used by CRPL and SPIM methods);
- the seasonal variation factor may be expressed in the form $|\log \rho| = \text{Const.} (\cos \chi_{\varphi=0})^m$ where χ is the value at local noon;
- there is appreciable absorption at night.

Previous contributions were:

1. the CRPL method described in the U.S.A. National Bureau of Standards Circular 462, published by the Government Printing Office, Washington 25, D.C., U.S.A.;
2. the method of Technical Report No. 9 of the U.S.A. Signal Corps Radio Propagation Agency, available as Catalogue No. PB103045 from the Office of Technical Services, Department of Commerce, Washington 25, D.C., U.S.A.;
3. the method proposed by the U.S.S.R., Doc. No. 744 of Warsaw, 1956, and later supplemented by charts for rapid calculation furnished to the Working Group for Resolution No. 48.

REPORT No. 156 *

SKY-WAVE ABSORPTION ON FREQUENCIES BETWEEN THE APPROXIMATE LIMITS OF 1.5 AND 40 Mc/s

(Study Programme No. 145 (VI))

(Los Angeles, 1959)

Additional information on absorption of radio waves propagated by ionospheric refraction has been collected since the VIIIth Plenary Assembly of the C.C.I.R.

Doc. VI/30 (Federal German Republic) of Geneva, 1958, presented an example depicting a decrease of field-strength in the frequency range between the FOT and the operational MUF. The operational MUF is defined by a minimum receiving field-strength of 1 $\mu\text{V/m}$, and the field-strength of the FOT was found to be about 30 db above 1 $\mu\text{V/m}$; the operational MUF was about 1.8 to 2.0 times the FOT. These observations were made on the circuit from New York (100 kW radiated power) to Detmold (Federal German Republic). Observations made during disturbed conditions of the ionosphere indicate that the decrease in field-strength occasionally extends over a greater range of frequencies than twice the FOT due to scatter.

* This Report was adopted unanimously.

Doc. VI/61 (France) of Geneva, 1958, describes absorption measurements made at oblique incidence over the (M.S.F.) Rugby (United Kingdom) — Bagneux (Seine, France) path 465 km long, on the standard frequency of 5 Mc/s. The hourly medians per month were determined for each of the 12 months of 1956.

The maximum values obtained refer to noon U.T. and lie between approximately 10 db (February) and 17 db (November). For each of the 12 months the cosine exponent of the zenithal angle of the sun was determined graphically. The values were between 0.76 and 1.38 according to the month. The variation in absorption as a function of the running mean R of the number of sunspots, studied for $\cos \chi = 0.75$ and 0.5, revealed that a large amount of additional absorption occurred systematically during the winter months over and above that governed by the zenithal angle and solar activity.

The Annex to Doc. VI/57 (France) of Geneva, 1958, gives, among other things, the hourly medians of the field per month of WWV (U.S.A.) recorded at Bagneux (Seine, France) on the standard frequency of 5 Mc/s, during the 12 months of 1956.

Since different modulations were used for the two stations (1000 and 400 c/s) MSF and WWV could be recorded separately with the help of narrow-band AF filters.

Doc. VI/54 (Japan) of Geneva, 1958, gives the results of field measurements of impulse transmissions at distances of 1000 km or under, of transmissions on 1.85, 2.5 and 4 Mc/s as well as of a continuous wave transmission on 4 Mc/s at a distance of 450 km. For transmission from JJY over a path 450 km long, and for $\cos \chi = 0.5$, the approximate values of absorption obtained were as follows:

10 db at 4 Mc/s.

18 db at 2.5 Mc/s.

24 db at 1.85 Mc/s.

Study of absorption variations as a function of the zenithal angle has shown that the best possible value of the exponent of $\cos \chi$ is unity.

A large abnormal increase in absorption was noted in winter.

A considerable amount of selective absorption occurred on 4 Mc/s received at a distance of 200 km.

The effect of multiple reflection on the values of field-strength on continuous waves was determined by comparing measurements made simultaneously on continuous and impulse waves respectively. A marked increase in the received field due to the influence of multiple reflections was revealed at night on continuous waves.

Doc. No. 90 (India) of Los Angeles, 1959, indicates the existence of appreciable absorption at night in tropical regions. Also presented are charts indicating temporal variation of absorption during the period from 1954 to 1957.

REPORT No. 157 *

**INTERMITTENT LONG-DISTANCE RADIO COMMUNICATION IN THE VHF
(METRIC) BAND BY MEANS OF SCATTERING FROM COLUMNS OF
IONIZATION PRODUCED BY METEORS IN THE LOWER IONOSPHERE**

(Study Programme No. 146 (VI))

(Los Angeles, 1959)

1. Introduction.

The subject of VHF transmission by reflections from columns of ionization produced by meteors (meteor trails) has been introduced into the C.C.I.R. in Report No. 54, where signals inadvertently so transmitted were considered in terms of their ability to cause interference. It is now clear that this transmission mode is useful for communications. Experimental single-channel two-way telegraph circuits have been operated in the 30 to 50 Mc/s frequency range over distances of 600 to 1300 km with transmitter powers of 1 to 3 kW. One-way transmissions of voice and facsimile have also been made with transmitter powers of one and twenty kilowatts respectively.

2. Summary of available information.

2.1 Relatively little information is available on the statistical characteristics of the small meteors important in this mode of transmission.

2.2 Theoretical computations indicate that for a given transmitter power *the average information transmission rate of an intermittent system can increase with increasing transmission bandwidth.*

2.3 Experimental results have indicated the possibility of useful transmission in bandwidths up to 100 kc/s.

2.4 Scattering by meteor trails can be highly directional in character and this property depends on geographic location, path orientation, and operating frequency.

BIBLIOGRAPHY

A general scientific reference on the characteristics of meteors is:

LOVELL, A. C. B. *Meteor Astronomy*, Oxford, (1954).

Characteristics of especial interest in radio transmission are summarized in:

VILLARD, O. G. *et al.* The Role of meteors in extended range VHF propagation. *Proc. I.R.E.*, **43**, 1473, (October 1955).

which contains numerous references to earlier work.

More recently most of an issue of the Proceedings of the I.R.E. has been devoted to this subject (*Proc. I.R.E.*, **45**, No. 12, (December 1957)). Some of the more important papers in this issue are:

FORSYTH, P. A., VOGAN, E. L., HANSEN, D. R. and HINES, C. O. *The principles of Janet — a meteor-burst communication system*, 1642.

* This Report was adopted unanimously.

- DAVIS, G. W. L., GLADYS, S. J., LANG, G. R., LUKE, L. M. and TAYLOR, M. K. *The Canadian JANET-system*, 1666.
- MONTGOMERY, G. *Intermittent communication with a fluctuating signal*, 1678.
- MONTGOMERY, G. F. and SUGAR, G. R. *The utility of meteor-bursts for intermittent radio communication*, 1684.
- VINCENT, W. R., WOLFRAM, R. T., SIFFORD, B. M., JAYE, W. E. and PETERSON, A. M. *A meteor-burst system for extended-range VHF communications*, 1693.
- VINCENT, W. R., WOLFRAM, R. T., SIFFORD, B. M., JAYE, W. E. and PETERSON, A. M. *Analysis of oblique-path meteor-propagation data from the communications viewpoint*, 1701.
- VON ESHLEMAN, R. *On the wavelength dependence of the information capacity of meteor-burst propagation*, 1710.

REPORT No. 158 *

REGULAR LONG-DISTANCE TRANSMISSION IN THE VHF (METRIC) BAND BY MEANS OF SCATTERING FROM INHOMOGENEITIES IN THE LOWER IONOSPHERE

(Study Programme No. 147 (VI))

(Warsaw, 1956 — Los Angeles, 1959)

1. Introduction.

Considerable experience has been obtained since the first high-speed communications circuits employing ionospheric scatter propagation came into regular service in 1953. Operation or experiment now extends from the Tropics to the Arctic and includes operation during a low solar-cycle minimum (1954) and an unprecedentedly high maximum (1957/1958). Furthermore, the importance of aspect-sensitive meteoric ionization in scattering power away from the receiving antennas is better understood. Since 1953, new terminal equipment of all kinds including antennae has been developed, and considerable attention has been given to the problem of reliability.

In the next sections a selected set of topics is discussed concerning which there is recent experience.

2. Solar-cycle dependence.

A long-term variation in signal intensities related to the well-known solar cycle would be expected and seems to be detectable during daytime. In high latitudes it appears to show some lag with respect to the sunspot cycle, which is interpreted as being an indication of dependence on magnetic disturbance activity. At times of high solar and magnetic activity daytime median signal intensities are higher by several decibels than during solar cycle minimum conditions. The differences are not constant, but vary with time of day, season, and path. The weaker signal intensities seem to be less dependent on solar activity than might be expected if they are representative of conditions when meteoric ionization is relatively important. In middle latitudes the results are similar, though magnetic effects are less noticeable. The solar-cycle dependence is far from simple to evaluate quantitatively, however, since its effects are complicated, for example in high

* This Report which replaces Report No. 64, was adopted by correspondence without reservation (see page 9).

latitudes, by absorption which tends to reduce signal intensities selectively at time of high solar and geomagnetic activity. Furthermore, the effect may well be obscured by long-term variations in meteoric ionization, unrelated to the solar cycle.

3. Useful range of frequencies.

The useful range of frequencies for ionospheric-scatter propagation is now usually accepted to extend from about 30 to about 60 Mc/s. At the lower end of the range, limitations are imposed by interference and long-distance back scattering, both propagated by the F2 layer. Long-distance back scattering is a form of self-interference which proved troublesome when it first occurred. Modulation techniques have now been developed which eliminate completely or in part back scattering as a source of difficulty for telegraphic communication. The occurrence of back scattering is therefore not a primary consideration in fixing a lower limit to the useful range of frequencies. On the other hand, the high-latitude absorption associated with an active sun is capable of reducing the signal-to-noise ratios to unusability in high-latitude applications for a rapidly increasing fraction of the time as the operating frequency is decreased below about 30 Mc/s. Indeed the absorption can be fairly serious for a significant fraction of the time even in the 30–40 Mc/s range at times of high solar activity, when the very highest reliabilities are sought.

At the upper end of the indicated range economic factors tend to be limiting. Since as a rough guide in the frequency range of interest the signal intensities may be taken as varying inversely as the seventh power of the frequency for scaled antennae, and the cosmic noise intensities inversely as about the 2.5 power of the frequency, the signal-to-noise ratio may be taken to vary approximately inversely as the 4.5 power of frequency. Thus the signal-to-noise ratio at 60 Mc/s would be about 4.5 ($10 \log_{10} 60/30$), or 13.5 db less than for 30 Mc/s. As a practical matter a receiving antenna for 60 Mc/s of the same aperture as one for 30 Mc/s based on current practice would be too directional and would therefore not realize much of the added plane-wave gain relative to a scaled antenna. Even if the figure of 13.5 decibels should represent an overestimate by several decibels, which seems unlikely, it will be seen that further increases in operating frequency would make the already high costs if not prohibitive, then certainly less competitive with other means of communication.

4. Two-frequency operation.

Because of considerations outlined above, increasing attention is being given to multiple frequency operation of ionospheric scatter services. Again because of economic arguments, and also because of spectrum problems, the possibilities of two-frequency operation are of particular interest. Two possible modes of operation are envisaged. The first is merely a simple extension of single-frequency operation and as such would have advantages of operational simplicity. In this scheme the lower frequency, for example in the 30–40 Mc/s band, would be used during years of low solar activity. Then when the solar activity had reached a level such that interference problems were becoming serious, the higher frequency would be used instead. By waiting for high solar activity it would be hoped that a few decibels of the disadvantage in signal-to-noise ratio incurred by raising the frequency would be offset in high latitudes at least by the solar-cycle dependence.

The second mode would require the lower frequency to be used as much of the time as possible—with its attendant advantages from a signal-to-noise viewpoint. The higher frequency would come into more extensive use, always on a short-term basis, as the level of solar activity increased. It would be brought into use at short notice only when an interference problem arose, or absorption effects became too serious. Thus the higher frequency would be used in varying amounts according to season, and time of day. Fortunately much of the interference is likely to occur at times

of day when signal intensities are high so that such temporary use of the higher frequency would be unlikely to lead to very serious degradation of the service. This would not be so, however, during long-distance F2-layer interference arising at times of day and year when the ionospheric-scatter signal intensities are naturally low, such as early evening periods near the equinoxes.

5. Modulation techniques and automatic error correction.

Meteor Doppler effects have led to the adoption of special FM techniques for telegraphic in which time rather than frequency division is used for multiplexing. 16-channel systems of 60-100 words/min are coming into use. Ionospheric scatter systems are not economically capable of providing sufficient bandwidth for extensive voice transmission, and are not likely to be much used for more than one or two voice channels. Automatic error-correction techniques, which are particularly effective when the natural character error rate is moderately high, will probably be highly effective in application to telegraphic traffic passed by means of ionospheric scatter.

6. Antenna and meteor effects.

The antenna problems centre about means for obtaining:

- maximum usable signal-to-noise ratios for constant transmitter powers;
- maximum protection against harmful multipath signal components; and to a more limited degree;
- maximum protection against harmful interference.

Large rhombics, which were much used in the earliest installations, are now disappearing in favour of more compact arrays with smaller gain and main-lobe directivity.

While current practice still favours antennae oriented along the great-circle path, thus favouring signal components arising from scattering near the path midpoint, it is by no means certain that this will continue much longer to represent good engineering practice. The importance of aspect-sensitive meteoric ionization which is most effective in regions of the ionosphere displaced transversely to the path direction is recognized. The effectiveness of such ionization varies greatly with time of day, season, meteoric activity, and path position, length, and orientation. By using antennae which take advantage of meteoric ionization from ionospheric regions other than the region above the path midpoint, it seems probable that the obtainable and usable signal-to-noise ratios will be substantially increased at certain times. Such increases will be of particular importance at seasons and times of day when the lowest signal-to-noise ratios occur for propagation via the midpoint region.

A fuller understanding of these matters based on careful experimentation will undoubtedly aid in the clarification not only of puzzling aspects of solar-cycle and frequency dependence, but also of problems involving the realized gains of antennae. Perhaps even the limits of the useful range of frequencies, and the need for and proper manner of operation with two frequencies will be better understood.

7. Reliability.

In the present state of the art it is found that the most serious problems affecting the reliability of communication services using ionospheric scatter propagation lie not in propagational factors, but in electrical, mechanical, electronic and human factors.

BIBLIOGRAPHY

1. BAILEY, D. K. *et al.* A new kind of radio propagation at very high frequencies observable over long distances. *Phys. Rev.*, **86**, 141-145, (1952).
2. BAILEY, D. K., BATEMAN, R. and KIRBY, R. C. Radio transmission at VHF by scattering and other processes in the lower ionosphere. *Proc. I.R.E.*, **43**, 1181-1230, (1955).
3. ABEL, W. G., DE BETTENCOURT, J. T., CHISHOLM, J. H. and ROCHE, J. F. Investigations of scattering and multipath properties of ionospheric propagation at radio frequencies exceeding the MUF. *Proc. I.R.E.*, **43**, 1255-1268, (1955).
4. BRAY, W. J., SAXTON, J. A., WHITE, R. W. and LUSCOMBE, G. W. V.H.F. propagation by ionospheric scattering and its application to long-distance communications. *Proc. I.E.E.*, **103**, Part B, 236-260, (1956).

In addition to the above, attention is drawn to substantial parts of issues of journals as follows:

5. *Proc. I.R.E.*, Vol. 43, **10**, (October 1955).
6. *I.R.E. Transactions on communications systems*, Vol. CS-4, **1**, (March 1956).
7. *Proc. I.E.E.*, **105**, Part B, (May 1958), containing under Session 1, the papers and discussion of a symposium on "Ionospheric Forward Scatter Propagation".
8. Docs VI/3, VI/51 and VI/62 of Geneva, 1958 which relate to Study Programme No. 147 (VI).

REPORT No. 159 *

FADING OF SIGNALS PROPAGATED BY THE IONOSPHERE

(Study Programme No. 148 (VI))

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

Doc. 92 (U.R.S.I.) of Warsaw, 1956 supports the intention of the C.C.I.R. to continue studies (a) on the mechanism of fading, especially at oblique incidence, and (b) on frequency and space diversity.

Doc. 298 (Poland) of Warsaw, 1956 points out, that two statistical distributions can be observed, especially for large distances, a Rayleigh distribution for weak fields and another with a different law for strong fields. These facts are proved by plotting the distribution for several short duration recordings on a Rayleigh diagram. A diagram is given for the diversity effect based on the assumption of Rayleigh distribution. Some formulae are derived, by which the ratio of field strengths can be determined when the values of the corresponding probabilities are known, or by how many times the radiated power must be increased to obtain a desired reception probability.

Doc. 147 (United Kingdom) of Warsaw, 1956 gives a study of the time and space distribution of amplitude by means of the autocorrelation function:

$$\rho(\tau) = e^{-\frac{\tau^2}{2\sigma^2}} \quad \text{and} \quad \rho(d) = e^{-\frac{d^2}{2\chi^2}}$$

respectively where σ and χ denote characteristic parameters for the time and space structure, σ being called the fading speed and χ the space structure size. Tests were made in the frequency range from 6 to 18 Mc/s over distances from 2000 to 17 000 km, and σ and χ were calculated from experimental measurements of the number of fades per minute and from the measured values

* This Report which replaces Report No. 59, was adopted by correspondence without reservation (see page 9).

of the correlation coefficients $\rho(d)$. It has been found that σ is reasonably independent of signal level and frequency with values between 0.5 and 2.5 seconds. The value of χ was found to lie between 150 and 400 m. Correlation measurements with polarization diversity gave values of between 0.14 and 0.33 corresponding to an equivalent spaced antenna separation of 240 to 480 m. The diversity gain, when correlation is not zero, is considered to suffer a loss of about 2 db, when $\rho = 0.6$.

Doc. 82 (Federal German Republic) of Warsaw, 1956 summarises the results of several years' recording time of WWV on 15 Mc/s at Darmstadt and of other radio links with shorter recording time. The median value of the field strength F_m , and the deviation σ for 30 minute periods were measured and were statistically treated over every sun rotation cycle. In the German document the deviation σ refers to the difference between the 10% and 50% or the 50% and 90% values. The corresponding median value F_M on the half-hour median values F_m , and the deviations σ_{Fm} for one sun rotation cycle were determined as well as the median values σ_M of the half-hour median values of the deviation σ . The deviation σ_σ of the half-hour deviations was also calculated. It was found that $\sigma_M = 6.5$ db (average of 28 sun rotations) with the rather small deviation $\sigma_\sigma = 1.55$ db. These two values for statistical short-time variability (half an hour) seem to be independent of field strength, frequency, or season. F_M and σ_{Fm} on the contrary show a marked seasonal and sunspot cycle variation which has not yet been fully analysed. The average value of σ_{Fm} is ≈ 9 db (average over 45 sun rotations) with a deviation of 2.5 db. The deviation σ_{Fm} can be regarded as a measure of the magnitude of day-to-day field-strength variations. (This concerns Study Programme No. 66 (VI), § 2 and 3.) Besides the random variation of F_m over a sun rotation, there exists a long period, non-random variation with a high maximum in winter and a second lower maximum in the early summer. As a measure of fading speed, the number of times the 90% field-strength level is exceeded per minute has been averaged over 28 sun rotations. The average obtained was 11.25 times per minute.

Docs. 76, 330 and 331 (Japan) of Warsaw, 1956 deal with the advantages of a new two-parameter time-distribution function, the so-called m -distribution. The m -distribution includes the Rayleigh distribution and approximates the log-normal distribution for longer observation times and under certain conditions. The m -distribution stands on a firm theoretical basis, and is equally well adapted for short and long-time intervals, for tropospheric as well as for ionospheric propagation. A simple transformation allows the influence of long periodic absorption effects to be included.

By measuring the variance $V(x)$ and the arithmetic mean $\bar{X}$ two parameters m and X_0 of the new distribution can be calculated and thereby the distribution completely determined. An apparatus has been developed and is described, by which an immediate measurement of $V(x)$ and $\bar{X}$, and thereby of m and X_0 , is effected. Diagrams have been plotted, from which the corresponding fading range $N(p)$ (e.g. $F(99\%) - F(1\%)$) can be read. Tests in the 7–12 Mc/s frequency range show m varying between 0.9 and 1.2. This corresponds to distributions which could be declared to be approximately log-normal. Further statistics of tests show how the m -value varies with time for particular frequencies and locations. Numerous short-time observations of the distribution for 1500 to 10 000 km propagation paths over 3 to 7 minutes, performed by a photometric method, support the theoretical statements and show that the m -distribution is well qualified as a general distribution for short time intervals.

Doc. 475 (U.S.S.R.) of Warsaw, 1956 reports field-strength measurements over a number of years and states the following facts:

- the distribution over periods not exceeding five minutes follows the Rayleigh law;
- the distribution of median values for a particular hour of every month is closer to log-normal with a standard deviation $\sigma = 8 \text{ db} \pm 1 \text{ db}$;
- over paths mainly crossing polar areas the distribution is not always log-normal. When it is, the standard deviation is about $\sigma = 12 \text{ db} \pm 5 \text{ db}$.

Doc. VI/16 (U.S.A.) of Geneva, 1958, gives a critical survey of Report No. 59 of the Warsaw meeting. It is stated that the calculations of space and time parameters σ and χ mentioned in this Report are based on the assumption of a Gaussian character of the correlation functions, an assumption which has not yet been sufficiently verified by experiments. Tests in the medium-frequency range indicate the validity of this assumption only in a very few cases. It is further pointed out that the two-parametric m -distribution for ratios of $m \geq 1$ is identical with the Rice distribution, which has been extensively used at least since 1949. It is suggested that in the analysis of amplitude distribution functions consideration should be given to the skewness of the distribution as an additional parameter. The skewness of the distribution varies in sign and might be used as an indication for geographical and time trends in the distribution. For distribution not varying greatly from normal, the use of the first two terms of a Gram-Charlier * type A series is suggested.

Doc. VI/17 (U.S.A.) of Geneva, 1958, gives a brief summary of the progress made in the last two to three years in the U.S.A. in the field of fading investigation. A bibliography completes this summary, which covers most of the six items of Study Programme No. 66.

With regard to short-period variations, a practical criterion for determining a suitable measurement period is discussed. The effects of the time constant of the measuring equipment on the fading depth, on the mean or median values and on the fading period, which are often neglected are pointed out. Pennsylvania State University's work in the frequency range 16–2400 kc/s proved the co-existence of at least two types of fading. Shallow fading with periods of about seven minutes was observed at and below 70 kc/s and a faster fading rate of about 1.5 minute periods, which dominates at a frequency of about 120 kc/s. Ground distances at which the fading became uncorrelated on 85 kc/s were about 5 km for the slow fading and 1 km for the fast. The rapid fading seems to have been due to irregularities above about 100 km, while the slower fading was due to random velocities of about 40 m/sec at the reflecting layer.

Numerous time and spatial correlation functions for 540 kc/s night-time transmission have been made by M.I.T. on the Boston-Washington, D.C. link. The average separation distance normal to the transmission path required to reduce the correlation to $1/e$ was 29.4λ , with a standard deviation of 17.1λ . This distance was found independent of signal strength and the presence of a specular component in the reflected wave. Very few autocorrelograms were found to be Gaussian. Measurements of the horizontal and vertical components of the field strength for a one hop F2-layer transmission over an east-west path of 1588 km on 13 Mc/s resulted in equal average amplitudes of both components, although the instantaneous ratios varied oppositely!

Effects of polarization diversity for 7 and 11.7 Mc/s New Jersey-Missouri transmissions showed that on 11.7 Mc/s the results corresponded to independent Rayleigh distributions of the two components; improvement was less on 7 Mc/s. Correlation of reception on space element antennae at medium-frequency was found to be $1/e$ for 90% of the time for a separation of 60λ . Variation of diversity advantage with degree of correlation for two spaced antennae was investigated. Statistics of the combined signal up to 10-fold diversity are also presented. Mobile observation on two pairs of VHF stations near Washington, D.C. showed high correlation of received signals, when the propagation paths and directions of propagation were the same, even though transmission frequencies were considerably separated, but showed no significant correlation when reception was from two opposite directions.

Statistical performance of a circuit when signal, noise or both are subject to Rayleigh fading is given. For 99.9% satisfactory performance 30 db more signal power is required in the presence of signal fading whether or not the noise is fading, and a 14 db improvement is obtained by a

* See Harold CRAMER: *Mathematical methods of statistics*, Princeton University Press, p. 222.

practical low-frequency dual-diversity system over that for non-diversity. Error rates in a synchronous frequency-shift system in the presence of receiver or thermal noise have been investigated.

Concerning mechanisms producing field-strength variations two types of fading for medium frequency have already been mentioned. Medium frequency autocorrelograms sometimes suggest that there are more than two different kinds of irregularities. Gaussian autocorrelograms, when observed, seemed associated with moderately high K -figures, suggesting that possibly at such times sufficiently high ionization at lower levels prevented reflection at high levels where smaller irregularities exist. Investigation of possible anisotropy of irregularities is being made. There is reason to believe they might be elongated in the direction of magnetic force lines.

In order to investigate fading effects on modulation, tests have been made on aural Morse code, frequency-shift teleprinter and voice modulation under typical carrier and noise conditions. A statistical method of estimating errors under multipath and fading conditions has been presented, and an acoustic analogue has been devised simulating time-varying multipath transmission for facilitating estimation of system performance. An extensive statistical study has been made of the performance of a communication system designed to operate under multipath conditions of transmission. System capacities are computed for cases of fixed and slowly varying multipath conditions which are supposed to be known by the receiver. The optimum receiver is specified as one which computes certain probabilities and makes decisions based on these computations. Autocorrelation of received signals is used to "sense" and "correct" for slow multipath variations.

Doc. VI/79 (U.S.S.R.) of Geneva, 1958, contains a continuation of the studies as described in Doc. No. 475 submitted to the VIIIth Plenary Assembly of the C.C.I.R. In March and October-November, 1956, field-strength measurements in the frequency range from 6800 to 18 000 kc/s over distances of 1500 and 6000 km were analysed with regard to the character of the amplitude distribution curves for the momentary values, for the median values and for all measured values during the total time of observation. The individual observation period for the determination of the median value amounted to two minutes. It was shown that the distribution of the momentary values followed a newly proposed three-parameter law, the distribution of the median values corresponded closely to the log-normal law, while the overall distribution could best be represented by a Gram-Charlier series.

Doc. VI/32 (Federal German Republic) of Geneva, 1958, is a continuation and extension of Doc. 82 submitted to the VIIIth Plenary Assembly and deals with field-strength recordings, measurement of fading frequency and space correlations of some North American, South American and Japanese short-wave radio links in the frequency range from 15 to 20 Mc/s at Darmstadt. The measurement of fading frequency or fading speed was accomplished on a statistical basis after inserting some very simple differentiating devices into the measuring circuit. The percentage distribution of the time derivative of a normalised field strength $\frac{dE}{dt}$ was measured in db/sec. The distribution for a large number of tests was shown to be log-normal with a median value of about 3.5 db/sec.

The day to day variations of field strength generally show a marked diurnal variation of the dispersion, with high values in the night-time and low values during the day, the maximum and minimum values for the 10% deviations (F_{10} — F_{50}) being approximately 20 and 5 db.

Numerous measurements of space correlation for British and North American short-wave stations in the frequency band between 10 and 21.6 Mc/s lead to the following results:

- the correlation coefficient r depends strongly on the propagation mode, with large values slowly decreasing with increasing antennae distance for specular reflection, and with low values rapidly decreasing, for scatter propagation;
- the correlation coefficient as a function of distance/wavelength respectively D/λ seems to be substantially independent of frequency;



- the correlation coefficient declines to a value of 0.5 for an antenna separation of $D/\lambda = 20$ along the direction of propagation and of $D/\lambda = 10$ perpendicular to this direction;
- for polarization diversity, ratios of 0.5 were found for specular reflection and of 0.25 for scatter propagation;
- for the scatter component of normal HF propagation, $r = 0.5$ is already obtained at $D/\lambda = 1$, when the distance D is normal to the propagation path;
- for specular reflection, nearby transmitting stations show higher correlation coefficients and vice versa.

Doc. 36 (Japan) of Los Angeles, 1959 presents a practical method of estimating the effect of modulation on fading, making the assumption that the modulation frequency is sufficiently higher than the rapidity of fading and that the modes of fading of the carrier and the sidebands are m -distributed (see Docs. 76, 330 and 331 (Japan) of Warsaw, 1956). Formulae are given which show that any kind of modulation gives a decrease $\Delta N(p)$ in the fading range, where p is a specified percentage of time defining the range $N(p)$. The modulation effect on the fading range is expected to be 4 db at most. Values of m obtained experimentally on 10 and 14 Mc/s coincided well with those estimated theoretically. Experiments on 15 Mc/s prove the adequacy of this method (see Doc. VI/17 (U.S.A.) of Geneva, 1958).

Docs. 88 and 91 (India) of Los Angeles, 1959. The analysis of amplitude distribution curves of field strength recording taken in the medium wave band and in the 5—15 Mc/s bands over distances from 600—1200 km reveal a Rayleigh, a linear-normal or a log-normal distribution of amplitudes, corresponding to reflections by local irregularities in a horizontal plane in the ionosphere, more or less superimposed on specular reflection from a regular layer. An analysis of the autocorrelation functions enables the determination of the r.m.s. velocity V_0 of the random motion of the irregularities in the direction of propagation. V_0 varies between 3.9 and 25.1 m/s and a linear relationship between V_0 and wavelength is obeyed. No correlation is found between the amplitude distribution of simultaneously recorded field strengths from oblique incidence CW transmission and vertical incidence pulse transmissions on an equivalent frequency. Auto-correlogram analysis is used to detect hidden periodicities in the fading record.

Conclusions.

Since the VIIth Plenary Assembly, progress has been made in the following items of Study Programme 66 (which has been replaced by Study Programme No. 148 (VI)).

Item (1)

the rapidity, severity and time distribution of short-period field-strength variations is undergoing further elucidation by short-time distribution measurements and the measurement of the time and space correlation coefficients. A time-structure parameter $\sigma = 0.5$ to 2.5 sec. and a space-structure parameter $\chi = 150$ to 400 m have been derived from the measurements of correlation coefficients in the 6 to 18 Mc/s range. A new distribution formula has been proposed, which is especially appropriate, in that it covers both short-time and long-time distributions;

Items (2) and (3)

the severity of day-to-day variations of hourly median field strength given as 10 db in Report No. 27 has been confirmed. New measurements over a period of several years gave variations of about $10 \text{ db} \pm 2 \text{ db}$, which seem to be reasonably independent of season and frequency. The figure 10 db represents, for a given hour, the difference between the hourly median exceeded on 10% of the days and the monthly median;

Item (4)

the effects produced by field-strength variations on different receiving systems, such as time, space, frequency and polarization diversity systems have been studied in an increasing number of documents both theoretically and experimentally. The influence of non-zero correlation on the diversity effect has been included. There still seems to be some discrepancy between the results of various workers with regard to the loss of diversity effect, when the correlation coefficient is not zero. Further studies are therefore necessary;

Item (5)

the mechanism of field-strength variations has been discussed in several contributions based on an analysis of amplitude distributions and autocorrelation functions. This investigation revealed the existence of both specularly reflecting layers and a layer with local irregularities in random relative motion against each other;

Item (6)

the effect of modulation on several fading parameters has also been investigated.

BIBLIOGRAPHY

1. NAKAGAMI, M. *Journ. Inst. Elec. Comm. Eng.*, Japan, **239**, 145, (Feb. 1934).
2. UHLENBECK, S. E. *Mass. Inst. Techn. Radiation Lab. Rep.*, **454**, (15 Oct., 1943).
3. RICE, S. O. *Bell Syst. Techn. Journ.*, **23**, 282, (1944).
4. *Ibid.*, **23**, 109.
5. *Ibid.*, **24**, 46.
6. NAKAGAMI, M. *Statistical studies on fading, diversity effects and characteristics of diversity receiving systems*, (1947).
7. MITRA, S. N. *Proc. I.E.E.*, P. III, **93**, 441, (1949).
8. MITRA, S. N. *Indian Journ. of Physics*, **24**, 195, (1950).
9. NAKAGAMI, M. and SASAKI, T. *Res. and Devel. Data No. 1*. Wireless system section, Elec. Comm. Lab. Japan, (May, 1950).
10. LAITENEN, P. O. and HAYDON, G. W. *N.S. Signal Corps. R.P.U. Techn. Rep. No. 9*, (Aug. 1950.)
11. MITRA, S. N. and ROY, J. N. *Electrotechnics*, **23**, 56, (1951).
12. MILLMAN, S. H. *Ann. Geophys.*, **8**, 365, (1952).
13. JONES, R. E. *Scientific Rep. No. 41*, the Pennsylvania State University, Ionosphere, Res. Lab. (1952).
14. NAKAGAMI, M. and FUJIMURA, S. *Journ. Inst. Elec. Comm. Eng.*, Japan, **36**, 234, (May 1953).
15. NAKAGAMI, M., WADA, S. and FUJIMURA, S. *Journ. Inst. Elec. Comm. Eng.*, Japan, **36**, 535, (Nov. 1953).
16. MATSUO, S. and IKEDA, F. *Res. and Development Data No. 9 Tel. Comm. Lab.*, Japan, (Aug. 1953).
17. RICE, S. O. *Proc. I.R.E.*, (Feb. 1953).
18. MAZUMDAS, S. C. and MITRA, S. N. *Ind. Journ. Phys.*, **28**, 251, (1954).
19. GROSSKOPF, I. *Fernmeldetechn. Zeitschrift*, 373, (1953).
20. JONES, R. E., MILLMAN, S. H. and NERTLEY, R. I. *J.A.T.P.*, **2**, 79-91, (1953).
21. GLASER, J. L. and FABER, L. P. *Proc. I.R.E.*, **41**, 1774-1778, (1953).
22. PRICE, R. T. *Res. Lab. of Electronics*, TR34 Lincoln Lab. Mass. Inst. of Techn., (3, Sept. 1953).
23. GROSSKOPF, I., VOGT, K. and SCHOLT, M. *Nachrichtentechn. Zeitschrift (NTZ)*, (1958).
24. GROSSKOPF, I. *Nachrichtentechn. Zeitschrift (NTZ)*, 114-118 and 146-152, (1955).
25. MITRA, S. N. and SCRIVASTAVN, R. B. L. *Indian Journ. of Phys.*, **31**, 20, (1957).
26. NAKAGAMI, M. and NISHIO, M. *Journ. Inst. Elec. Comm. Eng.*, Japan, (Oct. 1955).

27. NAKAGAMI, M. TANAKA, K. and KANEHISA, M. *Memoirs of the Faculty of Eng. Kobe Univ.*, **4**, 78, (1957).
 28. RATCLIFFE, J. A. *Reports on Progress in Physics*, **19**, 188, Physical Society, London, (1956).
 29. BOWHILL, S. A., *J.A.T.P.*, **11**, 2, 91-101, (1957).
 30. BRENNEN, D. G. and LINDEMAN PHILLIPS, M. *T.R.* 93, Lincoln Laboratory, Mass. Inst. of Technology, (16 Sept. 1957).
 31. PRICE, R. *Proc. I.R.E.*, **45**, 6, 879-880, (1957).
 32. LINDEMAN PHILLIPS, M. *Proc. I.R.E.*, **44**, 692.
 33. EVANS, R. D. *The Atomic Nucleus*, McGraw-Hill, New York, 903, (1955).
 34. BOWHILL, S. A. *J.A.T.P.*, **10**, 5/6, 338-339, (1957).
 35. BOWHILL, S. A. *J.A.T.P.*, **11**, 2, 91-101, (1957).
 36. BOWHILL, S. A. *Report Phys. Soc. Conference on Physics of the Ionosphere*, 308-319 (Sept. 1954).
 37. PIERCE, J. A. *Proc. I.R.E.*, **43**, 5, 584-588, (1955).
 38. BOWHILL, S. A. *J.A.T.P.*, **8**, 129.
 39. SALES, G. S. *Scientific Report No. 88*, The Pennsylvania State University, Ionosphere Research Lab. (1956).
 40. PARKINSON, R. V. *J.A.T.P.*, **8**, 3, 158-162, (1956).
 41. BRENNAN, D. G. and LINDEMAN PHILLIPS, M. *TR* 93, *Lincoln Laboratory, Mass. Inst. of Technology*, (Sept. 1957).
 42. HEDLUND, D. A. and EDWARDS, L. C. *Polarization fading over an oblique-incidence path*, Raytheon Mfg. Co., Wayland Lab. Wayland, Mass.
 43. SUGAR, G. R. *Proc. I.R.E.*, **43**, 10, 1432-1436, (1955).
 44. ABEL, W. G., DE BETTENCOURT, J. T., CHISHOLM, J. H. and ROCHE, J. F. *Proc. I.R.E.*, **43**, 10, 1255-1268.
 45. BAILEY, D. K., BATEMAN, R. and KIRBY, R. C. *Proc. I.R.E.*, **43**, 10 Fig. 7, 1189.
 46. STARAS, H. *J. Appl. Phys.*, **27**, 1, 93-94, (1956).
 47. STARAS, H. *Proc. I.R.E.*, **44**, 8, 1057-1058, (1956).
 48. BRENNEN, D. G. *Proc. I.R.E.*, **43**, 10, 1530, (1955).
 49. KIRBY, R. S. and CAPPS, F. M. *Trans. I.R.E.*, Ap-4, **1**, (1956).
 50. BOND, F. E. and MEYER, H. F. *Proc. I.R.E.*, **45**, 5, 636-642, (1957).
 51. PIERCE, J. N. *Diversity improvement in frequency-shift keying for Rayleigh fading conditions*, Electronics Research Directorate, U.S.A.F. Cambridge Research Centre, Sept. (1956).
 52. PETERSON, A. M., VILLARD, O. G., LEADABRAND, R. L. and GALLAGHER, P. B. *J. Geophys. Res.*, **60**, 4, 497-512, (1955).
 53. YERG, D. G. *J.A.T.P.*, **8**, 247-259, (1956).
 54. WATT, A. D., COON, R. M., MAXWELL, E. L. and PLUSH, R. W. *National Bureau of Standards, Report No. 5088*, (12 June 1957).
 55. ROOT, W. L. and PITCHER, T. S. *Trans. I.R.E.*, IT-1, **3**, (1955).
 56. DI TORO, M. J. (Abstract), *Proc., I.R.E.*, **40**, 746, (1952).
 57. PORTMAN, P. A. *Tech. Note 40*, *Westinghouse Electric Corporation*, Electronics Division, Baltimore, Maryland, (30 Sept. 1957).
 58. PRICE, R. and GREEN, Jr., P. E. *A Communication Technique for Multipath Channels*, Lincoln Lab. Mass. Inst. of Technology, (Aug. 1957).
 59. NORTON, K. A. *Proc. of Int. Congress on Propagation of Radio Waves at Liège (Belgium)*, (Oct. 1958) (to be published by the Academic Press).
 60. NORTON, K. A., RICE, P. L., JONES, H. B. and BARSIS, A. P. *Proc. I.R.E.*, **43**, 1341, (1955).
 61. RICE, S. O. *Bell Syst. Tech. Journ.* **31**, (1958).
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REPORT No. 160 *

**AVAILABILITY AND EXCHANGE OF BASIC DATA AND RELIABILITY
OF RADIO PROPAGATION FORECASTS**

(Study Programme No. 149 (VI))

(Geneva, 1951 — London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

1. Introduction.

Propagation of radio signals in the range 3—30 Mc/s over any but the shortest distances is practicable 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 which are determined by ionospheric characteristics. The operational range of frequencies has been found to be even more restricted with some forms of high capacity communications 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 forecasts (long and 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 forecasts are indicative of representative ionospheric conditions, thus it is extremely useful to operating personnel to be warned of impending ionospheric disturbances so that traffic can be re-routed, instructions can be issued in advance to cover temporary adjustments in the normal operating frequency, and direction-finder fixes can be assessed.

2. Available Radio Propagation Forecast Data.**2.1 Long-term forecasts.**

Organizations in several countries now prepare forecasts of ionospheric conditions up to twelve months in advance (see Annex); for general planning purposes, forecasts for a complete solar cycle are also made by some organizations. These forecasts are for representative ionospheric conditions. The information in most cases is 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 Short-term forecasts of disturbances.

Organizations in several countries now prepare short-term forecasts of ionospheric disturbances (see Annex). These forecasts are supplemental to the long-term forecasts, since the occurrence of ionospheric disturbances which cannot be forecast for long periods in advance may considerably modify 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 Annex).

2.3 Working documents for long-term forecasts.

The following documents are sources of MUF, FOT and field strength data for use with predicted sunspot numbers in making long-term forecasts:

* This Report which replaces Reports Nos. 55, 58 and 60, was adopted by correspondence without reservation (see page 9).



- P.F.B. (Provisional Frequency Board) (Geneva): Charts and Tables produced by C.R.P.L. at the request of the Atlantic City Conference (1947);
- I.H.F.B.C. (International High-Frequency Broadcasting Conference) (Mexico City): Graphs (1949);
- Australian I.P.S. Contour Maps (1947 and 1951);
- I.F.R.B. technical standards published by the International Telecommunication Union (1955—1959);
- Canadian Defence Research Telecommunications Establishment Report 1-1-3. "Prediction of Optimum Traffic Frequencies for Northern Latitudes" (1954).

Some of the above-mentioned data were produced when there was considerably less basic information and understanding of the physical properties of the ionosphere than exist now; discretion should be exercised in their use.

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 have been broadcast by certain countries in programmes known as Ursigrams arranged by the International Scientific Radio Union. 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, communications agencies and regional centres. The regional centres in turn exchanges once per day summaries of information on solar flares, sudden ionospheric disturbances, solar corona and radio noise, sunspots, ionospheric and magnetic activity, as well as forecasts. It should be noted that during the I.G.Y. (International Geophysical Year) a plan (established by C.S.A.G.I., on which U.R.S.I. has representation) has been in operation for rapid world-wide dissemination of similar information. The I.G.Y. regional centres in France, F.R. Germany, Netherlands, Japan, Australia and U.S.S.R. collect data in their regions and forward it by telegraph to the World Warning Agency (near Washington, D.C., U.S.A.) which has also collected data from its region. The World Warning Agency makes the final decision, having advice available from the other centres, whether or not to declare a world-wide ALERT (unusual solar activity expected) or an SWI (special world interval). These declarations are distributed to scientific stations participating in the I.G.Y. programme throughout the world by various rapid means, in particular over the meteorological teleprinter networks coordinated by the W.M.O.

3.2 The regional centres from which details may be obtained concerning data (solar flares, solar corona, solar radio noise, cosmic rays, critical frequencies of the ionosphere, terrestrial magnetism, ionospheric disturbances, and the quality of propagation) applicable codes and schedules of broadcasts and/or reports are listed in the Annex.

3.3 The Annex lists the centralizing agencies, which have been designated by their respective Administrations, for the reception, coordination, liaison and exchange of information relating to radio propagation.

4. Reliability of ionospheric propagation forecasts.

4.1 Introduction.

Reliability of ionospheric propagation forecasts was the subject of considerable study during the VIIIth Plenary Assembly of the C.C.I.R. (Warsaw, 1956) and (as evidenced by the reference made to other Recommendations, Study Programmes, and Reports in the several areas which are

treated in more detail), work has since continued. Comments on the MUF and LUF are made below, but it should be noted that knowledge of these alone is not sufficient to forecast circuit performance. The type of service and communication facilities must also be considered.

4.2 MUF.

It is recognised that considerable differences exist between the standard MUF as forecast and the operational MUF (see Report No. 161), Recommendation No. 318 and Study Programme No. 149 (VI). In many cases these differences are dependent upon the radiated power, antenna patterns of both the transmitting and receiving stations and upon the type of service (including information rate) as well as the particular method used in forecasting the standard MUF for the path.

4.3 Short-term forecasts.

In the declining phase of the sunspot cycle, the short-term forecasts tend to be more accurate than at other times as there is a strong tendency of disturbances to recur at 27-day intervals. The reliability of short-term forecasts has been considered in detail in Report No. 153.

4.4 LUF.

The main methods of forecasting the LUF are represented by the methods of C.R.P.L. and that of S.P.I.N. Insufficient experimental and operational data are available to assess the overall reliability, although many of the factors, such as field strength (Report No. 152), radio noise (Report No. 65, Recommendation No. 315) and the required signal/noise ratio (covered in Study Group III) are being independently evaluated.

ANNEX

LIST OF ORGANIZATIONS CONCERNED WITH THE EXCHANGE OF DATA AND THE ISSUING OF FORECASTS OF PROPAGATION CONDITIONS

- A: an agency for the general exchange of information on propagation;
- RC: a regional centre for the rapid exchanges of data required for short-term forecasts of disturbances;
- L: the organization issues long-term forecasts. The periods ahead for which forecasts are made are shown (in months);
- S: the organization issues short-term forecasts of disturbances;
- WDC: designated as a world data centre for the I.G.Y.

Country	Organization	Address	A	RC	L	S
Argentina	L.I.A.R.A.	Secr�ter�a de Marina D.E.N. L.I.A.R.A. Av. Lib. Gral. San Mart�n No. 327 Vincente L�pez Rep�blica Argentina	×		1	
Australia		Officer-in-charge, International Section, P.M.G.'s Department, Treasury Gardens, Melbourne C.2 Tel. address: Gentel, Melbourne.	×			
	I.P.S.	Ionospheric Prediction Service Sydney, New South Wales			3	
Belgium		Chef du Service du Rayonnement, Institut Royal M�t�orologique, 3, Avenue Circulaire, Uccle, Brussels	×			
Spain		Departamento de Servicios T�cnicos de Telecomunicaci�n Division General de Correos y Telecomunicaci�n Madrid	×			
United States	C.R.P.L.	Central Radio Propagation Laboratory, National Bureau of Standards Boulder, Colorado. (WDC)	×		6	×
		North Atlantic Radio Warning Service, Box 178, Fort Belvoir, Virginia		×		×
		North Pacific Radio Warning Service, Box 1119, Anchorage, Alaska		×		×
	R.C.A. Inc.	R.C.A. Incorporated 66 Broad Street, New York City				×
France	C.N.E.T.	Groupe ionosph�re du centre national d'�tudes des t�l�communications, 196, rue de Paris Bagneux (Seine) Tel. address: Gentelabo, Paris	×	×		×
	S.P.I.N.	Centre national d'�tudes des t�l�com- munications, Ch�teau de la Martini�re, Saclay (Seine et Oise)			6	
India		The Secretary, Radio Research Committee, National Physical Laboratories, Hillside Road, New Delhi	×		3	
		Kodaikanal Observatory				×
Italy		Istituto Nazionale di Geofisica Citta Universitaria, Rome. Tel. address: Geofisica, Rome (All messages should begin with the word " Ionosphere ")	×			

Country	Organization	Address	A	RC	L	S		
Japan	R.R.L.	Radio Research Laboratories, Ministry of Posts and Telecommu- nications, Kokubunji, Tokyo (WDC)	×	×	3	×	(³)	
New Zealand		Carter Observatory		×			×	
Netherlands		Afdeling " Ionosfeer en Radio-astro- nomie " Kortenaerkade 12, The Hague	×					
		P.T.T. Receiving Station Nederhorst-den-Berg		×				
Federal German Republic	F.T.Z.	Fernmeldetechnisches Zentralamt (Arbeitsgemeinschaft Ionosphäre) Rheinstrasse, 110, Darmstadt Tel. address: Ionosphäre, Darm- stadt	×	×	3		×	
United Kingdom	R.R.S.	Director, Radio Research Station, Slough, Buckinghamshire. Tel. address: Radsearch, Slough (WDC)	×		6			
Switzerland		Laboratoire de Recherches et d'Essais, Direction Générale des P.T.T., Speichergasse, 6, Bern	×					
Union of South Africa	C.S.I.R.	Telecommunications Research Labo- ratory, Department of Electrical Engineer- ing, University of Witwatersrand, Johannesburg	×		1			
U.S.S.R.	NIZMIR	Scientific Research Institute of Terres- trial Magnetism, Ionosphere and Radio Wave Pro- pagation, Moskovskaya Obl., P/O Vatutenki, Nizmir (WDC)	×	×	12 and 1		×	(⁴)

Notes: (1) Warnings also radiated from WWV and WWVH.

(2) Warnings radiated from Pontoise.

(3) Warnings radiated from JJY.

(4) Warnings radiated from RDZ and RND.

Note by the Director of the C.C.I.R.

Subsequent to the preparation of this report in Los Angeles, the following additional information has been furnished by China.

Country	Organization	Address	A	RC	L	S
China	R.W.R.L.	Radio Waves Research Laboratories, Directorate General of Telecom- munications, P.O. Box No. 84, Taipei, Taiwan	×		×	

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REPORT No. 161 *

BASIC PREDICTION INFORMATION FOR IONOSPHERIC PROPAGATION

(Study Programme No. 149 (VI))

(Los Angeles, 1959)

1. Prediction of oblique incidence MUF from vertical incidence data.

Different administrations, using both pulse and commercial transmissions, have shown that in medium latitudes there is a difference, usually positive, between the "classical MUF" (corresponding to refraction in a smooth curved layer) and "standard MUF" (as derived by the usual transmission curve methods). These comparisons have further shown that, depending on power and type of service, an appreciable difference (up to 25%) can exist between the "operational MUF" and the classical. Different types of ionospheric and ground scatter have been found as the origin of this difference.

2. Presentation of ionospheric charts.

It appears that continuity of the representation of ionization all over the world is the important feature to be achieved. The quantity to be represented, for example f_oF_2 , M3000 or MUF4000, should be a continuous function of three variables, latitude, longitude and time. The question whether L.M.T. or U.T. is used is secondary, since there is a linear relationship between longitude, L.M.T. and U.T.

The main problem is that of interpolation, which should be made preferably for points at the same local time, and should be on a physical basis, considering for example both solar and magnetic effects.

Experience is not yet sufficient to provide a definite answer concerning the best method of interpolation. This may be different in regions where the distribution ionospheric stations is dense from where it is sparse. Automatic interpolation methods appear to offer advantages over graphical methods.

3. Introduction of propagation modes.

It appears that only the French and German methods take modes of propagation into account explicitly in the construction of predictions (though not necessarily to the fullest extent). This has given results considerably different from those obtained by the two-control-point method, but no information is available as to which method is the more accurate, nor is it certain that they refer to the same conditions. Work on modes of propagation is also proceeding in the U.S.A. and the United Kingdom.

It would appear that in due course one or more methods will be available, whereby modes of propagation and elevation angles of arrival and departure could be computed.

In cases of very long distance transmission the wave usually experiences a series of reflections. A number of conditions must be fulfilled in order to achieve adequate received field strength if the propagation path lies partly in daylight and partly in night-time conditions. Special methods make allowance for different propagation paths and the effect of the E layer.

* This Report was adopted unanimously.

4. Introduction of anticipated day-to-day spread in MUF.

From independent analyses it is apparent that although the mean value of the lower decile of the MUF is close to 0.85 (i.e. the present FOT), the spread of this lower decile can be from approximately 0.72 to 0.90. It appears that this spread is dependent on various factors, including seasonal and solar effects.

Doc. No. 37 (Japan) of Los Angeles, 1959, defines a FOT for a minimum loss operation time (MLFOT) based on mathematical statistics involving the probability distributions of F2 and Es propagation.

5. Other predictions.

The U.S.S.R. has presented some interesting preliminary results with regard to the prediction of curves of h' as a function of f , the parameters of which can be used for the calculation of the classical MUF and in other questions of propagation (e.g. antenna patterns).

A Netherlands contribution proposes predictions based on some thirty possible ionospheric models which allow for variation in the critical frequency of the E and F-layers and in the height of the F-layer. Single hop calculations can be made of MUF, skip distance, etc. based on these models. The case can then be selected which most nearly approaches the existing conditions.

REFERENCES

Docs. VI/10, VI/37, VI/46, VI/48, VI/57, VI/70, VI/73 and VI/78 of Geneva, 1958.
Docs. Nos. 22, 29, 37, and 162 of Los Angeles, 1959.

REPORT No. 162 *

CHOICE OF A BASIC INDEX FOR IONOSPHERIC PROPAGATION

(Study Programme No. 150 (VI))

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

1. Introduction.

The aim of this interim report is to explain, in more detail than has been possible in Study Programme No. 92, the way in which some basic indices could be used in practice and to state clearly what is meant by ionospheric propagation in the context of this Study Programme. It will then be easier to visualize the objectives of the study and to direct attention to particular problems relating to indices and their use, which have not yet been solved.

2. The control of key frequencies by solar activity.

The preparation of an ionospheric prediction implies the preparation, three, six or more months in advance, of estimated values of MUF, FOT, and LUF at a given time and for a given pair of terminal stations. These "key frequencies" vary with the time of day, the month, and

* This Report which replaces Report No. 57, was adopted unanimously.

the level of solar activity. If solar activity remained constant, the key frequencies would recur regularly every year and a permanent set of tables of them could be compiled. The need for ionospheric forecasting services arises only because of the variations in solar activity.

3. Types of solar activity.

It is very important to distinguish between three different types of solar activity which affect the ionosphere in completely different ways:

3.1 *photon radiation*, which is responsible for the normal E and F layers and which determines the key frequencies during undisturbed conditions;

3.2 *corpuscular radiation*, which is thought to be the main cause of the ionospheric disturbances which result in changes, lasting for a day or two, in the key frequencies;

3.3 *flares*, during which a type of photon radiation is emitted which raises the LUF by a large amount, usually for not more than about one hour.

To make an accurate prediction of the key frequencies for some future date, it would ideally be necessary to have predicted values of three indices representing photon, corpuscular and flare radiation respectively.

4. Ionospheric predictions.

Even under favourable conditions, the key frequencies for a particular day cannot be predicted with useful accuracy more than about one month in advance. Hence a long-term prediction normally refers only to the monthly mean frequency for the month in which the day falls. For the undisturbed days, the key frequencies are controlled mainly by solar photon radiation which produces the ionization in the E and F layers. Thus an index $\overline{I_p}$ is required which represents the monthly mean value of the photon radiation flux emitted from the whole of the sun's surface.

The monthly mean index, $\overline{I_p}$, represents the main trend of the solar cycle and its month to month changes. It is important to remember, however, that the rotation of the sun on its axis introduces a component having a period of 27 days which is smoothed out in $\overline{I_p}$. Hence, to make a prediction for a particular day, the daily values, I_p , of the photon index are required. The amplitude of the 27-day component is very variable and it can only be estimated, with any worth-while accuracy, about one month ahead of the date for which the prediction is required.

It is well known that, in addition to the photon radiation just mentioned, the sun emits corpuscular radiation which may cause the key frequencies on a given day to depart from the values which would be expected for the actual value of I_p . It is necessary, therefore, to have a daily index, I_c , which represents the flux of corpuscular radiation. Such an index, however, cannot usually be predicted more than about one month in advance.

During a solar flare, a particular type of photon radiation is emitted which has an appreciable effect, for a short time only, on the LUF. The flare may be accompanied by corpuscular radiation which may reach the earth's atmosphere a day or two later. Flares occur suddenly in certain types of active sunspot and their occurrence is very difficult to predict. It appears, therefore, that three indices are required for the prediction of key frequencies:

$\overline{I_p}$, a monthly mean index of photon radiation which allows the mean key frequencies for the month in question to be predicted several months in advance;

I_p , a daily index of photon radiation which allows the key frequencies for a given undisturbed day to be predicted about one month in advance;

I_c , a daily index of corpuscular radiation which may allow a correction to be made to the key frequencies predicted using I_p .

The predictions of monthly mean frequencies which are issued by several countries at present are based on the assumption that the month will contain the number of disturbed days expected from previous experience. This is equivalent to the use of a composite index $\overline{I_{cp}}$ which is some unknown function of $\overline{I_p}$ and I_c .

5. Potentially useful indices.

A *useful index* is assumed to be one which is predictable and which is closely correlated with the ionospheric parameter for which predictions are required.

5.1 Indices of corpuscular radiation.

The derivation of an index of corpuscular radiation is closely related to the problems involved in Study Programme No. 93 (VI) which deals with the investigation of precursors of ionospheric disturbances. It appears, at present, that the problems of the identification of such precursors and of the production of an index of corpuscular radiation are essentially the same. For this reason, it seems appropriate that only some possible indices of photon radiation should be considered in this report.

5.2 Indices of photon radiation.

Since the MUF and FOT are controlled mainly by the critical frequency, $foF2$, of the F2 layer, the most important characteristic of the index $\overline{I_p}$ is that, for each month of the year, it should be closely correlated to the monthly mean value of $foF2$. Other important attributes of such an index are that it should be reasonably easy to produce, that observational errors should be as small as possible, and that it should preferably be possible to compute it from measurements made in any part of the world.

5.3 Relative sunspot number (R).

The monthly mean values of $foF2$, for a given month and hour, and R are closely correlated but the correlation coefficient is greater if 12-month (R_{12}) or 3-month running mean values of R are used. The main reason for using R_{12} in ionospheric prediction work at present is that many investigations have been carried out on methods of predicting R_{12} .

Comparisons have often been made between the twelve-month running means of R and $foF2$ but the resulting relations seem to vary from one solar cycle to another and a possible reason for this has been suggested by Minnis [1]. Even if the running mean of R could be predicted accurately, there would still be considerable uncertainty in the prediction of $foF2$ for the central month of the period. This point is referred to in a Czechoslovakian document [2].

The main advantage of R is that a fairly homogeneous series of monthly values covering twenty solar cycles is available. Hence it is the only index which can be used for the study of the statistics of the solar cycle over a long period. Another merit of R is that its magnitude is not controlled, to any important degree, by terrestrial influences.

5.4 Solar radio-noise flux at microwave frequencies (Φ).

Regular measurements of solar noise flux have been made in Canada at 2800 Mc/s since 1947, and in Japan at 3260 and 3750 Mc/s since 1951. At these frequencies, the noise originates near the levels in the solar atmosphere from which the main ionizing photon radiation is emitted. It

might be expected, therefore, that the correlation between solar noise flux, Φ , and the E layer character figure discussed in § 5.5 should be high. This has been confirmed, using monthly mean values, by Denisse and Kundu [3], and by Minnis and Bazzard [4] who quote correlation coefficients of about 0.95 when each month is considered separately. French [5], American [6] and United Kingdom [7] documents suggest that both the daily and monthly mean values of Φ ought to be considered as basic indices for ionospheric studies. A U.S.S.R. study [18] shows no advantage of this index compared with sunspot numbers as an index for long-term predicting.

5.5 E layer character figure (Ch_E).

The critical frequency, foE , of the normal E layer and the solar zenith angle, χ , can be used to compute the E layer character figure: $Ch_E = (foE)^4 \sec \chi$ [8, 16]. With certain reservations, Ch_E may be assumed to be proportional to the flux of the photon radiation which is responsible for the E layer. It has been shown by Minnis and Bazzard [4, 10], that Ch_E contains a small seasonal component, but a method of eliminating this has been devised and the resulting corrected index is referred to as I_E . For values of I_E based on measurements made at a single station, errors in reading foE may lead to errors in the daily values of I_E of up to about 10%. The corresponding error in the monthly mean I_E is much less. Data given by Allen [9] can be used to show that for a given level of solar activity, I_E varies with the latitude of the observing station. If I_E were adopted as an index, values measured at different latitudes could be adjusted to give the value at the equator or at some other standard latitude.

5.6 The F2 layer index (I_{F2}).

The method of producing this index has been described by Minnis [1]. A line is fitted to the points representing the monthly mean of $foF2$ and R_3 , the 3-month weighted mean of R . For any measured value of $foF2$, the fitted line can then be used to obtain the corresponding value, R'_3 , of R_3 . The index I_{F2} is the mean value of R'_3 for the monthly means of $foF2$ at Huancayo, Slough and Watheroo. The very small response of I_{F2} to changes in geomagnetic activity indicates that the index is not sensitive to corpuscular radiation. It seems reasonable, therefore, to use I_{F2} as an index closely related to the intensity of the F2 layer photon radiation. It is important to note, however, that I_{F2} is not proportional to the radiation flux as I_E probably is.

Since the plots $foF2 = f(R_3)$ mentioned above are linear up to about $R_3 = 170$, the relations between $foF2$ and I_{F2} are also linear. The only points which depart by a large amount from the linear relation are those for the exceptional period September 1957—January 1958.

5.7 Combined indices.

Work has recently started in the Netherlands on the development of a general index derived from a combination of individual indices [17].

The advantages and disadvantages of these indices have not yet been fully investigated and it is still premature to make a final decision as to which of them is likely to be the best one to adopt for use by the C.C.I.R. The remarks which follow summarize the position as it was in October 1958:

6. Relative merits of Φ , I_E and I_{F2} .

6.1 Correlation with monthly mean $foF2$.

The correlation between monthly mean values of noon $foF2$ and I_{F2} has been examined in the United Kingdom for about 60 well-established observatories and found to be high. The relations are linear even at high levels of solar activity, and world contour maps of the intercept and slope can be drawn without much difficulty between latitudes 70° N and 60° S. No sufficiently representative evidence is available on the correlation between $foF2$ and Φ and between

$foF2$ and I_E , but some sample plots indicate that the relations are not linear. This is to be expected because the statistical relations connecting I_{F2} with Φ and I_E are not linear [10].

6.2 Derivation of the index in different countries.

The solar noise flux could be measured directly in any part of the world but the agreement between the different measurements would depend on the accuracy which could be achieved. Medd and Covington [11] refer to possible systematic errors of about $\pm 7\%$ in their data.

I_E involves the extrapolation of foE to its value for a hypothetical overhead sun but the value obtained depends on how the extrapolation is made and whether a latitude correction has been applied. A sample of daily values for Puerto Rico and Maui suggests that agreement within ± 0.1 Mc/s is possible [6].

No information is available on any differences which there may be between the values of I_{F2} based on the three stations used by the United Kingdom [1] and other possible combinations of stations.

6.3 Significance of daily values of indices.

A study by Kundu and Denisse [12] is referred to in a French document [5] which suggests that daily values of Φ may be useful in ionospheric studies.

Daily values of I_E can be calculated but it may be desirable to introduce some smoothing by averaging over several hours per day or by using averages over several days [6].

Daily values of I_{F2} have not been studied but it seems likely that they will be more sensitive than the monthly mean values to changes due to corpuscular radiation and to the complex dynamical phenomena which exert short-term effects on the F2 layer. For this reason, daily values of I_{F2} may be difficult to interpret and to use.

7. Tables of indices.

Daily values of Φ at microwave frequencies, measured at several observatories are published by the International Astronomical Union [13]. The Ottawa data should be used in conjunction with the corrections discussed by Meedd and Covington [11].

Monthly mean values of I_E and I_{F2} have been given by Minnis and Bazzard [10] in a paper which also reproduces the corrected monthly mean values of Φ at 2800 Mc/s, measured in Ottawa. Daily values of I_E are under investigation in at least the U.S.A. and the United Kingdom but no published tables are available at present.

8. Transmission quality figures.

The indices discussed in the previous sections are intended to represent the changes in the solar radiation which controls the main characteristics of the ionosphere. The ionospheric changes, in turn, cause corresponding changes in the performance of operational radio circuits. The study of the relation between basic ionospheric characteristics and radio circuit performance is a complicated one because it is difficult to express, in a quantitative manner, all the factors which determine the performance.

This problem has been referred to by Beckmann [14] and has also been discussed in a document of the Federal German Republic [15]. A *band quality figure*, K , is defined which depends on the difference between the MUF and LUF for a given path, and on the mean field strength, $\bar{E}$, of signals received over this path from a number of transmitters. Thus $K = (1 + MUF - LUF) \log \bar{E}$ (MUF and LUF in Mc/s). Polar diagrams of K for paths radiating from a given point show the general reduction in quality which is caused by ionospheric disturbances, and also the more pronounced changes which occur in certain directions. An index of this type should be useful for

the study of geographical influences on circuit performance and also as a method of indicating the onset of short-term deteriorations in quality caused by ionospheric disturbances or by short-term changes in solar photon radiation.

9. Conclusions.

The investigation of the relative merits of several alternative basic indices of solar activity is in progress in several countries. It is not yet possible to decide which of these indices is most appropriate to the needs of the C.C.I.R.

BIBLIOGRAPHY

1. MINNIS, C. M. *J. Atmos. Terr. Phys.*, **7**, 310 (1955).
2. Document No. VI/65 of Geneva, 1958.
3. DENISSE, J. F. and KUNDU, M. R. *C.R. Acad. Sci.*, Paris, **244**, 45 (1957).
4. MINNIS, C. M. and BAZZARD, G. H. *Nature*, Lond. **181**, 1796 (1958).
5. Document No. VI/55 of Geneva, 1958.
6. Document No. VI/11 of Geneva, 1958.
7. Document No. VI/34 of Geneva, 1958.
8. APPLETON, E. V. and NAISMITH, R. *Phil. Mag.*, **27**, 144 (1939).
9. ALLEN, C. W. *Terr. Mag. Atmos. Elec.*, **53**, 433 (1948).
10. MINNIS, C. M. and BAZZARD, G. H. *J. Atmos. Terr. Phys.* (in course of publication).
11. MEDD, W. J. and COVINGTON, A. E. *Proc. I.R.E.*, N.Y., **46**, 112 (1958).
12. KUNDU, M. R. and DENISSE, J. F. *J. Atmos. Terr. Phys.*, **13**, 176 (1958).
13. *Quart. Bull. Solar Activ.*, I.A.U., Zürich.
14. BECKMANN, B. *Fernmeldetechn. Z.*, **7**, 285 (1954).
15. Document No. VI/44 of Geneva, 1958.
16. Document No. 149 of Los Angeles, 1959.
17. Document No. 229 of Los Angeles, 1959.
18. Document No. 154 of Los Angeles, 1959.

REPORT No. 163 *

PULSE-TRANSMISSION TESTS AT OBLIQUE INCIDENCE

(Study Programme No. 151 (VI))

(Los Angeles, 1959)

1. Characteristics of long distance ionospheric propagation obtained by pulse transmission.

Detailed experimental investigations have been reported by various Administrations in Docs. Nos. VI/19 (U.S.A.), VI/48 (and VI/53 (Japan), VI/43 and VI/46 (Federal German Republic), and VI/35 (United Kingdom), of Geneva, 1958, and in Doc. No. 26 (Federal German Republic) of Los Angeles, 1959.

Special attention has been paid to the problems of the so-called "nose extension" and of echoes from auroral ionization (Doc. VI/46 of Geneva, 1958, and Doc. 29 of Los Angeles, 1959). Diffuse

* This Report was adopted unanimously.

traces caused by “continental scatter” (ground forward scatter) have been observed with pulse transmission from England to Japan (Doc. VI/48 of Geneva, 1958) but seem not to have been observed in the opposite direction. An interesting series of simultaneous measurements of the angle of arrival and pulse delay time are reported (Doc. VI/35 of Geneva, 1958).

Some preliminary results concerning the reciprocity problem have been given in Doc. VI/19 of Geneva, 1958; also the difficulties of identification and the appearance of combined modes containing E- and F- reflections for large East-West distances are stated in this report.

2. Intercomparison of experimental MUF with midpoint soundings.

Experimental M -factors determined from sweep-frequency records have been compared with variously derived theoretical values. This has especially been done in Doc. VI/53 (Japan), of Geneva 1958, for various layers, including E and Es. Also, the ratio of the lowest transmitted frequency at oblique incidence to the vertical incidence $f_{min}F$ observed near noon was observed to remain sensibly constant during the two months when this investigation was carried out.

The frequency difference between the two magneto-ionic rays has been studied in the United Kingdom (Doc. VI/35 of Geneva, 1958) as well as in Japan (Doc. VI/53 of Geneva, 1958). In both cases the difference at oblique incidence with a nearly North-South path was not very different from that at vertical incidence.

Doc. 29 (Federal German Republic), Los Angeles, 1959, describes measurements showing the classical $1 \times F_2$ MUF on a 1965 km path to be 7% above that calculated from vertical soundings at the path midpoint. Equivalent frequencies determined from the point of tangency of a transmission curve applied on the high angle trace of an oblique incidence ionogram were in good agreement with the critical frequency derived from the vertical soundings.

3. Synchronization and display techniques.

Sweep-frequency techniques have been used by all of the four Administrations mentioned under § 1. Detailed descriptions of techniques are given in Doc. VI/53 (Japan) and Doc. VI/35 (United Kingdom) of Geneva, 1958.

REPORT No. 164 *

LONG-DISTANCE IONOSPHERIC PROPAGATION WITHOUT INTERMEDIATE GROUND REFLECTIONS

(Study Programmes Nos. 151 (VI) and 152 (VI))

(Los Angeles, 1959)

There is now evidence from several sources that there are modes of propagation, presumably by means of the regular ionospheric layers, in which waves can travel to great distances by a low absorption path without intermediate ground reflections:

* This Report was adopted unanimously.

1. Back scattering experiments in the United Kingdom have shown long range echoes out to 10 000 km which are stronger than multi-hop echoes present at the same time at shorter range. They sometimes persist after the multi-hop echoes have faded out [1].
2. Oblique-incidence pulses are received in the United Kingdom by way of a single-hop transmission from Ottawa, Canada by means of a high-angle or Pedersen ray [2]. It is improbable, however, that the Pedersen mode could be transmitted over much greater distances with widely different ionospheric conditions along the route.
3. It has been known for many years that at certain times high frequency communication can be maintained over very long distance paths when the signals are not receivable near the mid-point of the route [3].
4. Round-the-world echoes occurring at times favourable for transmission along the twilight zone are remarkable for their low dispersion and the small attenuation between successive echoes [4].
5. Closely related to these phenomena is the ability to work at times on frequencies well above the MUF predicted from vertical incidence data.
6. These considerations all point to the conclusion that the energy must pass through long stretches of the ionosphere without intermediate ground reflections, possibly in the region between the upper side of the E layer and the lower side of the F layer where the absorption would be very low. Rocket measurements show, however, that the trough between the E and F layers can be very small [5].
7. It has more recently been shown that such propagation is also possible within a single layer for certain general types of electronic distribution, the wave reflected down near the level of maximum density being reflected up again from a level near the lower boundary of the layer [6, 7].

With idealized models in which the density is a function of the height only, such modes would have to be excited within the region, because a ray that entered from outside, e.g. from below, would by symmetry emerge again. It may be necessary, therefore, to invoke a mechanism by which the energy can be got into such a mode, and it has been suggested that this might be achieved by a process of scattering or by a tilt in the layer at the point of entry. A similar mechanism (scattering or tilt) may be invoked to enable the energy to emerge at the end of the route where it eventually reaches the receiver. In fact it would seem that both tilted layers and scattering have a profound effect on long distance ionospheric propagation.
8. It is of interest to note that once a ray has been deflected by a layer tilt into the requisite direction, the possibility can exist of it emerging from the ionosphere and travelling in a straight line path that remains above the earth and re-enters the ionosphere [1].
9. The mechanism of propagation by a series of internal reflections within a layer or region suggests the alternative, or equivalent, explanation in terms of transmission along a leaky wave-guide. This description is particularly illuminating in attempting to explain the characteristics of round-the-world echoes.
10. Round-the-world echoes have recently been observed on ionospheric scatter transmissions [8] and on satellite signals [9]. The opportunity of establishing transmitters which spend part of their time in the ionosphere, and hence occasionally within a favourable duct, may greatly advance the study of the problems discussed in this report. They will also continue to come within the scope of Study Programmes Nos. 151 (VI) and 152 (VI) by the use of pulse transmissions and back-scattering techniques.

BIBLIOGRAPHY

1. Doc. VI/33 and VI/20 of Geneva, 1958. Discussion of first paper of ref. 3, p. 523. STEIN, S. *Journ. Geophys. Res.* **63**, 217, (1958).
2. WARREN, E. and HAGG, E. L. *Nature*, **181**, 34 (1958); KIFT, F. *Nature*, **181**, 1459-1460 (1958).
3. HUMBY, A. M., MINNIS, C. M. and HITCHCOCK, R. J. *Proc. I.E.E.*, 102 B, 513-522, 1955; SMALE, A. J. *J.I.E.E.*, **94**, Part III A, 345, (1947).
4. HESS, H. A., *P.I.R.E.*, 1948, **36**, 981; DE VOGT, A. H. *Onde Elect.*, **30**, 433, (1950); VON SCHMIDT, O. *Zeitschr. f. Tech. Phys.*, **17**, 443, (1936).
5. JACKSON, J. E. and SEDDON, J. C. *Jour. Geophys. Res.*, **63**, 197, (1958). Doc. 209 of Los Angeles, 1959.
6. Doc. 122 of Warsaw, 1956, Doc. VI/40, VI/64 and VI/84 of Geneva, 1958, *Nature*, **181**, 105, (1958).
7. Doc. 301 of Warsaw, 1956, Doc. 210 and 211 of Los Angeles, 1959.
8. ISTD, G. A. *Marconi Review* **131**, 173-183, (1958).
9. MILLINGTON, G. *Proc. I.E.E.*, **105** B, 95, (1958) (Contribution to Discussion on Radio Observations on the Russian Satellites).

REPORT No. 165 *

MEASUREMENT OF ATMOSPHERIC RADIO NOISE

(Study Programme No. 154 (VI))

(Los Angeles, 1959)

1. Networks of noise measuring stations.

Under this heading it is proposed to list those stations at which measurements are made which yield values of noise power directly comparable with Report No. 65. Stations measuring more complex statistical parameters of noise will be dealt with in § 4.

The network initiated and supervised by the U.S.A. in accordance with Recommendation No. 174, consists of 16 stations measuring noise power (and other parameters) mostly of 8 frequencies. It is hoped that this network can be gradually extended by cooperation between the U.S.A. and other administrations.

The U.S.S.R. has 12 stations, each operating on several out of a range of 10 frequencies. The stations measure the amplitude probability distributions of noise, from which the power can be calculated.

The United Kingdom supervises three stations measuring amplitude probability distributions, and deriving the noise power. In addition, nine stations continue to use the Thomas method, most on ten frequencies, and conversion to noise power is achieved through direct comparisons between the two methods at one or two stations. Australia also uses the Thomas method at medium and high frequencies; data are available from five stations and it should be possible to derive conversion factors to noise power.

Japan records amplitude probability distributions at two frequencies in the HF range, and values of noise power are derived.

Considerable noise data exist in France, from which it might be possible to derive values of noise power. It is proposed to measure noise power in France in the future.

Data from these stations should be suitable for checking the contours, the frequency laws, and the ratio of the upper and lower decile to median values of noise predicted in Report No. 65.

* This Report was adopted unanimously.

2. Comparison between different methods.

During the next two or three years there should be sufficient measurements made for the Thomas noise values to be adequately correlated with measurements of noise power for various geographical regions. Thereafter it may not be necessary to continue the Thomas measurements solely for purposes of comparison, although they could usefully be continued at locations where no alternative method exists and where data already collected are inadequate.

At Singapore, Malaya, and Ibadan, Nigeria, measurements are being made with both the U.S.A. type of automatic equipment and with the United Kingdom equipment for measuring amplitude probability distributions, thus affording direct comparisons of derived noise power values.

3. Facilities for locating thunderstorm centres.

Extensive facilities now exist, mainly under the control of meteorological organisations, for the location of thunderstorms at a distance, using direction finding techniques. The information from these facilities could usefully be related to measurements of noise power on types of directional aerials in common use for radio services. Report No. 65 presents data on the noise power received on a short vertical aerial, and the expected statistical variations of this power with time. Similar information is required for directional aerials, with which both the mean noise power and its statistical variations may be expected to depend on the orientation of the aerial relative to main sources of noise.

Unfortunately, very few measurements of the noise power received on directional aerials have been made. More such measurements are required in areas where there are suitable receiving aerials and facilities for locating thunderstorms at a distance. The received noise power should be studied in relation to the distribution of storms so that the reception of noise power on directional aerials in other parts of the world can be predicted from thunderstorm data.

4. Statistical properties of atmospheric noise.

The opinion of U.R.S.I., that the amplitude probability distribution of atmospheric noise is a useful partial description of its wave-form characteristics, is noted. Measurements of this type are in progress in the U.S.S.R., U.S.A., United Kingdom and Japan, as detailed in the report on § 1. Existing data include amplitude probability distributions at a number of frequencies in the range 10 kc/s to 20 Mc/s.

In addition to the amplitude probability distributions, measurements are also made, by all of the above administrations and by France, of the crossing-rate, the frequency with which the noise envelope exceeds a threshold or series of thresholds.

5. Presentation of statistical data on noise.

The best means for presenting information on amplitude probability distributions for C.C.I.R. purposes has yet to be determined, but it seems probable that for the time being a simple tabulation of certain points on the distribution curve will be more useful than the approximate empirical formulae suggested by U.R.S.I. in a report to the C.C.I.R.

6. Relative importance of atmospheric noise and other forms of interference.

Little information has been presented on this topic, and its continued study is necessary in order that special emphasis in studies of atmospheric noise can be given to those frequencies and locations where it is the main factor limiting communication.

SECTION H

STANDARD-FREQUENCIES AND TIME SIGNALS

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REPORT No. 166 *

STANDARD FREQUENCIES AND TIME SIGNALS TRANSMISSIONS

(Question No. 140 (VII))

(Warsaw, 1956 — Los Angeles, 1959)

On the occasion of the Ninth Plenary Assembly, certain points concerning the establishment and functioning of a world wide standard frequency and time signal service, in the bands allocated to the service, were resolved. The principal remaining problems are the following:

1. Certain areas of the world have no suitable service.
2. The signal-to-noise ratio is too low in many industrial areas.
3. Many users require higher accuracy; in the allocated bands, however, deterioration in the course of propagation appears to prevent sufficiently accurate measurements from being made in a period of a few minutes.
4. Optimum characteristics of time signals and receiving equipment, for obtaining the highest accuracy, have not yet been completely determined.
5. The standard frequency service continues to experience interference from stations which are not standard frequency stations but which operate in the bands allocated to this service.
6. The problem of interference between standard frequency stations operating at the same time on the same carrier frequency has not been resolved, and serious difficulties are experienced by specialized users in some locations. The number of stations operating simultaneously has increased. Since the Eighth Plenary Assembly studies and modifications in the services have indicated ways of avoiding a number of the difficulties mentioned above. For example:
 - some stations have a complete break in transmission at regular intervals,
 - two stations are using one side band only for the modulation on an experimental basis,
 - another station transmits modulation with the carrier suppressed.

Several types of time signals have been studied. The form recommended by the Sixth Plenary Assembly of the C.C.I.R., consisting of m cycles of a modulation of $200\ m\ c/s$, still appears to be satisfactory for most users; however, it is hoped that additional experimental work will lead to improvement, e.g. a break of the carrier wave and the insertion of a time signal of short duration may permit better separation of multipath signals; and improved reception may result from an increase in radiated power of the time signal. With the present system it appears desirable that each station use a different modulation frequency to form the time signal in order to identify the station.

The possibility of using different forms of time markers to indicate physical and astronomical time was discussed. It was agreed to refer this matter to the U.R.S.I.

It is hoped that it may be possible to publish expeditiously in the *Telecommunication Journal* any new information on standard frequency and time signal transmissions. The transmission characteristics are also given in the List of Special Service Stations. It is important that each Administration should prepare and distribute a booklet kept up to date, describing its technical services in the field of standard frequency transmissions. Information on the exact shape of the time pulse radiated would be particularly useful.

* This Report which replaces Report No. 66, was adopted by correspondence without reservation (see page 9).

The errors occurring in the course of standard frequency and time signal propagation and the need for a high degree of accuracy in measurements taken over a relatively short space of time, have compelled the Study Group to undertake further studies. Two Questions have been continued: No. 142 (VII), "Standard frequencies and time signals in new frequency bands", and No. 186 (VII), "Stability of standard frequencies and time signals at reception". The trend toward greater accuracy is becoming more and more apparent.

It may be noted that station GBR on 16 kc/s has for some time been operating with its carrier frequency derived from the same oscillator as that controlling the standard-frequency transmitter MSF. Results of measurements at great distances confirm that great accuracy can be obtained on frequencies of this order.

The Study Group drafted Resolution No. 53 "That the next Administrative Radio Conference be requested to provide for an international standard-frequency and time signal service in Band 4; a suitable frequency being in the neighbourhood of 20 kc/s (15 to 25 kc/s) with a required bandwidth of about 100 c/s".

The use of atomic resonance devices has resulted in a more constant frequency standard being available. A higher precision is needed in time signals and a new Study Programme No. 156 (VII) was formulated "Frequency spectrum conservation with high precision time signals".

Five new stations in the bands allocated have been brought into operation since the Eighth Plenary Assembly of the C.C.I.R. Particulars of all the stations as of April, 1959, are set out in Annex I to this Report entitled "The main characteristics of standard frequency transmissions and time signal stations". Annex III gives the geographic locations. It is encouraging to note that there are now three stations in the southern hemisphere. It should again be stressed that existence of too many stations in a given region can injure rather than improve the efficiency of the service. There is at present no coordination of the timing of transmission breaks at different stations; a world wide programme of these breaks would lead to an important reduction of mutual interference. The same thing is true concerning the limitation of the number of frequencies sent out simultaneously by a given station. The degree of interference, as well as the extent of the areas served, depends largely on the radio propagation conditions which have not yet been taken into consideration in the proposals for coordination. Audio modulation causes more interference than time signals. Finally, mutual interference would be reduced by the use of various offset carrier frequencies distributed in each allocated band, in combination with single side band modulation. The Chairman of Study Group VII in cooperation with the Director of the C.C.I.R., the Administrations concerned, and the I.F.R.B. has been requested to study the problem of reducing mutual interference e.g. by time sharing and frequency offsetting (Recommendation No. 319). Such methods, if introduced, would result in the modification of some of the characteristics set out in Annex I of the present report.

It is to be noted that Recommendation No. 319 calls for an accuracy which is higher than that prevailing at some stations listed in Annex I. It is hoped that the administrations will attempt to meet the Recommendation as soon as possible.

A number of standard frequency and time signal stations operate on frequencies outside the bands allocated to this service. Such stations known in April 1959 are mentioned on Annex II. They are especially interesting since their results could aid in answering the Question No. 142 (VII) mentioned earlier. In this connection the possibility of stabilizing the carrier frequencies of existing transmitters operating in the bands between 15 and 500 kc/s with a high degree of accuracy should receive careful study. Recommendation No. 320 deals with these problems.

There is still a need for clearing the frequency bands allocated exclusively to the standard frequency service. Recommendation No. 321 deals with this problem.

The forecasts of propagation, which indicate the present and future state of the ionosphere, for certain parts of the globe have been continued at WWV, WWVH, JJY. In addition to the important information which they give for radio communication and research work, these forecasts can be utilized in high accuracy work, for determining the possibilities of the reception of standard-frequencies and time signals for any specified period.

The use of special transmissions as proposed in Study Programme No. 94 — "Use of special modulation on the standard frequency transmissions for assessing the reliability of propagation

forecasts" was essentially replaced by Study Programme No. 155 (VII). These items were coordinated with Study Group VI and it was decided to continue the study of frequency staggering which will assist propagation measurements.

To sum up, Study Group VII considers that Atlantic City (1947) Recommendation No. 2 has already been satisfactorily implemented in broad outline. Nevertheless, certain problems have not yet been fully solved; moreover, the degree of accuracy required by the user is continually increasing. The work of Study Group VII should be continued.

ANNEX I

MAIN CHARACTERISTICS OF STANDARD FREQUENCY

Stations	BUENOS AIRES Argentina	HAWAII United States of America	LOWER HUTT New Zealand	MOSKVA U.S.S.R.	NEUCHÂTEL Switzerland	NEW-DELHI India
Latitude Longitude	34° 37' S 58° 21' W	20° 46' N 156° 28' W	41° 14' S 174° 55' E		46° 58' N 6° 57' E	28° 34' N 77° 19' E
Call sign	LOL	WWVH	ZLFS		HBN	ATA
Carrier power to antenna (kW)	2	2	0.03	20	0.5	1 (21)
Type of antenna		Vertical dipole			Horizontal dipole	Horizontal dipole
Number of simult. transmissions	6	3	1	1	1	1
Number of carriers used	6	3	1	2	2	1
Transmis- sions	Days per week	6 (1)	7	1 (9)	6 (1)	7
	Hours per day	5 (2)	23 (6)	3 (10)	½ (11)	24
Standard frequencies used	Carriers (Mc/s)	2.5; 5; 10; 15; 20; 25	5; 10; 15	2.5	10 (12) 15 (13)	2.5 (16); 5 (17)
	Modulations (c/s)	1 (3); 440; 1000	1 (6); 440; 600	Nil	1 (14)	1 (18); 500 (19)
Duration of audio modulation (minutes)	4 in each 5 (4)	3 in each 5 (7)	Nil	Nil	5 in each 60	4 in each 15
Frequency accuracy (parts in 10 ⁹)	± 20	± 10	± 100	± 20		± 20
Max. value of steps of frequency adjustments (parts in 10 ⁹)		5		20	0.5 (20)	20
Duration of time signal transmis- sions (minutes)	4 in each 60	Continuous	Nil	5 in each 30 (15)	5 in each 10	Continuous
Accuracy of time intervals	± 20 × 10 ⁻⁹ ± 1 µs	± 10 × 10 ⁻⁹ ± 1 µs	Nil		± 10 × 10 ⁻⁹ ± 1 µs	± 20 × 10 ⁻⁹ ± 1 µs
Method of time signal adjust- ment	Approx. 20 ms	By steps of 20 ms (8)	Nil		Steering	By steps of 20 ms

AND TIME SIGNAL STATIONS IN APRIL 1959

OLIFANTS- FONTEIN South Africa (28)	PARIS France	PRAHA Czecho- slovakia	ROMA Italy	RUGBY United Kingdom	TOKYO Japan	TORINO Italy	UCCLE Belgium	WASHINGTON U.S.A.
25° 58' S 28° 14' S	48° 46' N 2° 20' E	50° 07' N 14° 35' E	41° 52' N 12° 27' E	52° 22' N 1° 11' W	35° 42' N 139° 31' E	45° 03' N 7° 40' E	50° 48' N 4° 21' E	39° 00' N 76° 51' W
ZUO	FFH	OMA	IAM	MSF	JJY	IBF		WWV
4 (23)	0.3	1	1 (39)	0.5	2	0.3	0.02	0.1 – 10
Omnidirec- tional (29)	Inverted L	T	Horizontal dipole	(43)	Vertical (46)	Horizontal dipole (51)	Vertical	Vertical dipole
1 (23)	1	1	1	3	3–4	1	1	6
1 (23)	3 (27)	1	1	3	4	1	1	6
7	2 (28)	7	6 (1)	7	7	6 (1)	7	7
24 (24)	9 (29)	24 (35)	1 (40)	24 (44)	24 (47)	1 (52)	22 (54)	24 (55)
5 (23)	2.5; 5 (30) 10 (30)	2.5	5	2.5; 5; 10	2.5 (48); 5; 10; 15	5	2.5	2.5; 5; 10; 15; 20; 25
1 (25)	1 (31); 440; 1000	1 (36) (37) 1000	1 (41); 440; 600; 1000	1 (38) 1000	1 (49) 1000	1 (53); 440; 1000	Nil	1 (56); 440; 600
Nil	10 in each 20 (32)	4 in each 15	8 in each 15 (42)	5 in each 15	4 in each 5	5 in each 10 (4)	Nil	3 in each 5 (7)
± 20	± 20 (33)	± 20	± 20	± 5 (33)	± 20	± 20	± 10	± 5
1	20	1	20	10	10	20		0.5
Continuous	10 in each 20	10 in each 30 (38)	5 in each 15	5 in each 15	Continuous	5 in each 10	Nil	Continuous
± 20 × 10 ⁻⁹ ± 1 µs	± 20 × 10 ⁻⁹ ± 1 µs	± 20 × 10 ⁻⁹ ± 1 µs	± 20 × 10 ⁻⁹ ± 1 µs	± 5 × 10 ⁻⁹ ± 1 µs	± 20 × 10 ⁻⁹ ± 0.3 µs	± 20 × 10 ⁻⁹ ± 1 µs	Nil	± 5 × 10 ⁻⁹ ± 1 µs
By steps of 20 ms (26)	By steps of 50 ms (34)	Steering	By steps of 50 ms	By steps of 20 ms (45)	By steps of 10 ms (50)	By steps	Nil	By steps of 20 ms (8)

NOTES

- (1) Working days.
- (2) From 1100 to 1200, 1400 to 1500, 1700 to 1800, 2000 to 2100 hours and 2300 to 2400 hours U.T.
- (3) Pulses of 5 cycles of 1000 c/s tone; no 59th pulse of each minute.
- (4) Alternately 440 or 1000 c/s.
- (5) Interruption from minute 0 to minute 3, from minute 15 to minute 18, from minute 30 to minute 34 and from minute 45 to minute 48 of each hour, and from 1900 to 1933 hours U.T.
- (6) Pulses of 6 cycles of 1200 c/s tone; no 59th pulse of each minute.
- (7) Alternately 440 or 600 c/s.
- (8) Adjustments are made on Wednesdays at 1900 hours U.T., when necessary.
- (9) Tuesdays.
- (10) From 0100 to 0400 hours U.T.
- (11) From 0715 to 0745 hours U.T.
- (12) Even days.
- (13) Odd days.
- (14) Signals A1 keyed. Duration of each signal 100 ms; the first signal of each minute is prolonged.
- (15) From 0715 to 0718 and from 0743 to 0745 hours U.T.
- (16) From Saturday 0700 hours to Tuesday 0700 and from Wednesday 0700 hours to Friday 0700 hours U.T.
- (17) From Tuesday 0700 hours to Wednesday 0700 hours and from Friday 0700 hours to Saturday 0700 hours U.T.
- (18) 5 carrier interruptions, each of 1 ms and spaced by 1 ms. The beginning of the first interruption indicates the exact second. The complete minute signal comprises 250 successive interruptions.
- (19) Square wave modulation.
- (20) Relative to a molecular standard.
- (21) Further 2.
- (22) From 0530 to 0600 and from 1030 to 1100 U.T. Further during 22 hours.
- (23) Identical transmissions by Johannesburg (26° 11' S, 28° 04' E) with 0.3 kW on 10 Mc/s using a horizontal dipole with a maximum radiation: N-S.
- (24) Interruption from minute 15 to minute 25 of each hour and from 0630 to 0700 hours U.T.
- (25) Pulses of 5 cycles of 1000 c/s tone; the first pulse of each minute being prolonged (500 ms).
- (26) Thursdays, if necessary.
- (27) Provisionally 1.
- (28) Tuesdays and Fridays.
- (29) Interruption from minute 25 to minute 30 of each hour.
- (30) Subsequently.
- (31) Pulses of 5 cycles of 1000 c/s tone, the first pulse of each minute is prolonged to 100 ms and followed by 440 c/s tone lasting 100 ms.
- (32) 440 c/s during 1 minute, then 1000 c/s during 9 minutes.
- (33) Relative to an atomic standard.
- (34) If required, the first Monday of each month.
- (35) Interruption from minute 40 to minute 45 of each hour.
- (36) Pulses of 5 cycles of 1000 c/s tone; the first pulse of each minute is prolonged (100 ms).
- (37) The first pulse of each 5th minute is prolonged to last 500 ms. The last 5 pulses of each quarter of an hour last 100 ms. Pulses of 100 cycles of 1000 c/s tone from minute 55 to minute 60 of each hour. The first pulse of each minute is prolonged (500 ms).
- (38) From minute 20 to minute 25 of each hour, no time pulses.
- (39) Peak power during audio modulation with suppressed carrier: 0.8 kW.
- (40) From 0730 to 0830 hours U.T.
- (41) Pulses of 5 cycles of 1000 c/s tone; the first pulse of each minute is repeated 4 times.
- (42) Carrier suppressed during audio modulation.
- (43) Vertical monopole for 2.5 Mc/s; horizontal quadrant dipoles for 5 and 10 Mc/s.
- (44) Interruption from minute 15 to minute 20 of each hour.
- (45) If necessary, adjusted on the first day of each month.
- (46) Two half-wave dipoles on 15 Mc/s; one half-wave dipole on 2.5 and 5 Mc/s.
- (47) Interruption from minute 29 to minute 39 of each hour.
- (48) From 0700 to 2300 hours U.T.
- (49) Break in transmission during 20 ms, the break before second 0 lasting 200 ms.
- (50) On Friday, if necessary.
- (51) Maximum radiation: NW-SE.
- (52) From 0700 to 0730 and from 1100 to 1130 hours U.T.
- (53) Pulses of 5 cycles of 1000 c/s tone; the first pulse of each minute is repeated 7 times at intervals of 10 ms.
- (54) Interruption from 1130 to 1230 and from 2030 to 2130 hours U.T.
- (55) Interruption from minute 45 to minute 49 of each hour.
- (56) Pulses of 5 cycles of 1000 c/s tone; no 59th pulse of each minute. The first pulse of each minute is repeated 100 ms later.

ANNEX II

MAIN CHARACTERISTICS OF STANDARD FREQUENCY AND TIME SIGNAL STATIONS
OPERATING OUTSIDE THE EXCLUSIVE BANDS IN AUGUST 1958

Stations	Boulder United States of America	Main- flingen Federal German Republic	Ottawa (5) Canada	Poděbrady Czecho- slovakia	Rugby United Kingdom	
Latitude Longitude	40° 00' N 105° 15' W	50° 01' N 09° 00' E	45° 18' N 75° 45' E	50° 08' N 15° 08' E	52° 22' N 1° 11' W	
Call sign	KK 2XEI	DCF 77	CHU	OMA	GBR	MSF
Power of carrier-wave in antenna (kW)	2	12	0.3 (6) 3 (?) 5 (8)	5	300	10
Type of antenna	Omni- directional	Omni- directional	½ wave fol- ded dipole (6) (?) E-W Rhomb. (8)	T		
Number of simultaneous transmissions	1	1	3	1	1	1
Number of carrier frequencies used	1	1	3	1	1	1
Trans- missions	days per week	5 (1)	6 (1)	7	7	7
	hours per day	6.5 (2)	11 (3)	24	24	22 (12)
Standard- frequencies used	Carriers (kc/s)	60	77.5	3330; 7335; 14670	50	16
	Modulations (c/s)	Nil	1 (4); 200; 440	1 (9)	Nil (13)	Nil (13)
Duration of audio modulation	Nil		Nil	Nil	Nil	5 in each 15
Accuracy of frequencies (parts in 10 ⁹)	± 0.5	± 10	± 10 (10)	± 20	± 5 (14)	
Maximum value of frequency adjustment hops (parts in 10 ⁹)	0.5		20	1	10	
Duration of time signal transmissions	Nil	(4)	Continuous	Contin- uous (11)	(15)	5 in each 15
Accuracy of time intervals	Nil		+20 × 10 ⁻⁹ (10)			± 5 × 10 ⁻⁹ ± 1 μs
Method of time signal adjustment	Nil		By steps of 20 ms	Steer- ing		By steps of 20 ms (18)

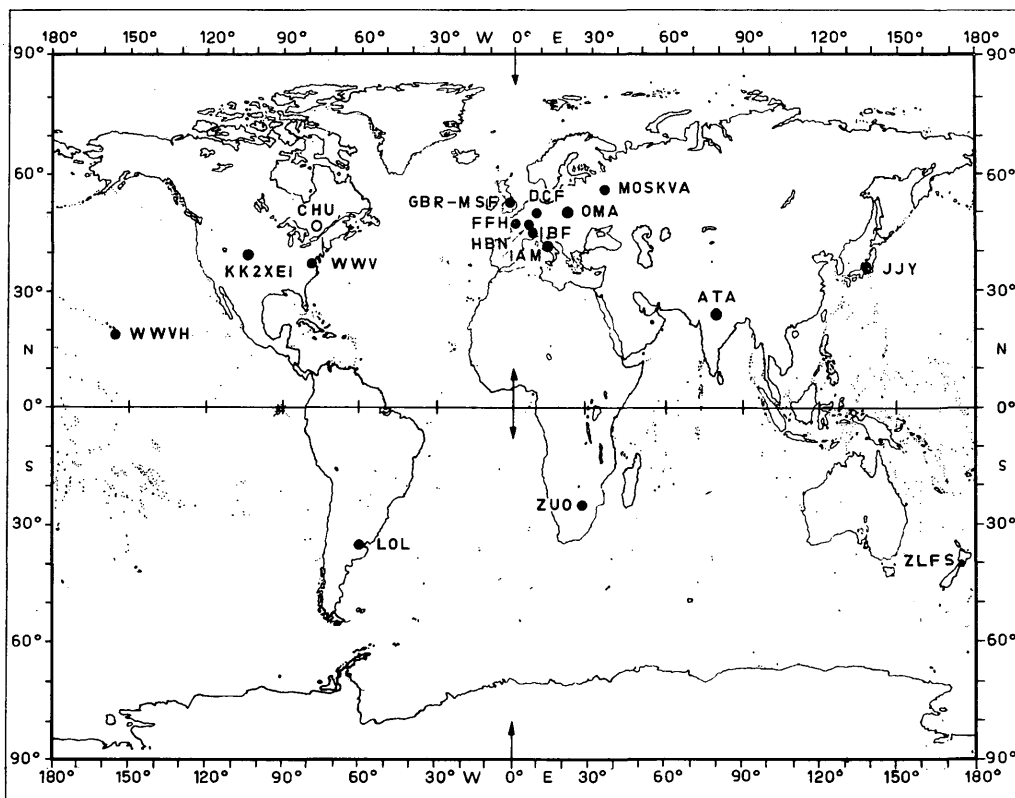


NOTES

- (1) Workdays.
- (2) From 1530 to 2200 hours U.T.; continuous with atomic control from 1530 U.T. Wednesdays to 2200 U.T. Thursday.
- (3) From 0700 to 1110 and from 1900 to 0210 hours U.T. between 1 March and 31 October; from 0700 to 1110 and from 1900 to 0010 hours U.T. between 1 November and end of February.
- (4) International type A1 telegraph time signals from the Deutsche Hydrographische Institut from 0800 to 0810, from 1100 to 1110 U.T., and from minute 0 to minute 10 of each hour between 1900 and 0210 (or 0010) and between 1930 and 1940 hours U.T.
A1 telegraph reference time signals from the Physikalisch-Technische-Bundesanstalt from 0728 to 0759, from 0811 to 1004, from 1028 to 1059, from 1911 to 1929, from 1941 to 1959 hours U.T., and from minute 57 to minute 59 of each hour between 1957 and 0159 (or 2359) hours U.T.
- (5) At the end of 1959.
- (6) On 3330 kc/s.
- (7) On 7335 kc/s.
- (8) On 14670 kc/s.
- (9) Pulses of 200 cycles of 1000 c/s tone; the first pulse of each minute is prolonged.
- (10) ± 1 when used with published corrections.
- (11) Continuous A1 telegraph time signals during 23 hours a day. From 1000 to 1100 U.T.; 50 kc/s standard frequency transmission without any keying, except call sign OMA at the beginning of each quarter of an hour.
- (12) Depending on telegraph traffic.
- (13) A1 telegraphy.
- (14) Relative to a Caesium atomic standard.
- (15) International type time signals from 0955 to 10-00 and from 1755 to 18-00 hours U.T.
- (16) From 1430 to 1530 hours U.T.
- (17) Pulses of 5 cycles of 1000 c/s tone; the first pulse of each minute is prolonged (100 ms).
- (18) If necessary, adjusted on the first of each month.

ANNEX III

WORLD-WIDE DISTRIBUTION OF STANDARD-FREQUENCY AND TIME SIGNAL STATIONS



- Station in service
- ◐ Low-power station operating on 2-5 Mc/s
- Projected station

SECTION J

MONITORING OF TRANSMISSIONS

No.	Title	Page
167	Automatic monitoring of occupancy of the radio-frequency spectrum	395
168	Measurements at mobile monitoring stations	396
169	Frequency measurements at monitoring stations	402
170	Field-strength measurements at monitoring stations	406
171	Identification of radio stations	412
172	Spectrum measurement at monitoring stations	414

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REPORT No. 167 *

**AUTOMATIC MONITORING OF OCCUPANCY OF THE RADIO
FREQUENCY SPECTRUM**

(Question No. 143 (VIII))

(Los Angeles, 1959)

Question No. 143 (VIII) was assigned to Study Group VIII by the Eighth Plenary Assembly of the C.C.I.R. at Warsaw in 1956. The following is a report of progress to date, as summarized from responses to this question. (Docs. VIII/7, VIII/9, VIII/11, and 186 of Los Angeles, 1959).

1. In addition to the factors limiting the accuracy of measurements of bandwidth by manual devices, other factors contribute to the inaccuracies when the measurements are made by automatic means. Examples of these factors are, the requirement that an unattended receiver be capable of responding to any bandwidth and type of emission that may be encountered; at the same time retaining good characteristics for narrow as well as wide emissions, transient effects which tend to limit the selectivity of the filters that may be used, and for large differences between average and instantaneous values of the same emission. Accuracies of bandwidth measurements have been obtained which are within 10 to 20% of those obtained using high resolution spectrum analysers.

2. With regard to the accuracy of field strength measurements made by automatic devices, the principal limiting factors are the determination of effective antenna height and directivity for the wide band of frequencies being scanned and the methods used to establish signal levels. An automatically switched attenuator calibrated in 6 db steps has been used. Noting at which steps of the attenuator the receiving equipment fails to respond to the signal, gives the approximate values of the signal strength. Accuracies of about 13 db have been obtained.

3. Methods used for measurement of field strength may also be used to determine the signal to noise ratios. Differences in the settings of the attenuator between signal and no signal conditions for the same receiver output are a measure of the signal to noise ratio. Accuracies comparable to those obtained for field strength are realizable.

4. A method of analysis and evaluation of graphical monitoring records is suggested by which a system of facsimile would be used to copy graphical records from different sources on a common evaluation sheet. Several days of occupancy records might be summarized on a single sheet (Doc. No. VIII/7 of Los Angeles, 1959).

5. Another type of equipment now in use is called an "occupancy-vacancy recorder". This system indicates by an inked line on a strip recorder the presence or absence of signal. As the instrument scans the spectrum, a continuous line is drawn on the chart to indicate the presence of signals. In the absence of a signal, the recorder and frequency scanning mechanism stop for a pre-set interval. If no signal appears during this interval the recorder makes a dot on the chart, the system moves forward a small increment and repeats the procedure. When signals are again encountered the device moves on steadily until the next vacant spot is found. The equipment is provided with a special circuit that automatically adjusts the sensitivity to one of two pre-set

* This Report was adopted unanimously.

values, the sensitivity being changed alternately at the end of each scan. Each scan makes a new trace, roughly parallel to the previous one. In this manner approximately 48 hours of data can be placed on a single strip. A new model of this equipment, now being developed, will also indicate approximate values of signal strength.

REPORT No. 168 *

MEASUREMENTS AT MOBILE MONITORING STATIONS

(Question No. 144)

(Study Group No. VIII)

(Los Angeles, 1959)

Question No. 144 asked for information on the capabilities of mobile monitoring stations to make measurements of various kinds and the limitations and accuracies of such measurements. A number of contributions, Docs. VIII/1, VIII/3, VIII/14 and VIII/19 of Los Angeles, 1959 provide details of measurements and methods presently in use in various countries and enable the following statement to be made:

1. Types of measurement.

Subject to the limitations necessarily imposed by mobile operation, the size of suitable instruments and power consumption, it is considered to be practical to employ mobile stations to make all the measurements of emissions normally made at fixed monitoring stations.

Typical measurements and ranges are—

1.1	Frequency measurement	10 kc/s	to above 300 Mc/s.
1.2	Field strength measurement	10 kc/s	to above 300 Mc/s.
1.3	Bandwidth measurement	10 kc/s	to above 300 Mc/s.
1.4	Direction finding:		
	with loops	10 kc/s	to 20 Mc/s.
	with dipole arrays	20 Mc/s	to above 300 Mc/s.
1.5	Automatic monitoring of occupancy	10 kc/s	to above 300 Mc/s.
1.6	Percentage modulation, F.M. Deviation	10 kc/s	to above 300 Mc/s.
1.7	Video Waveform measurement of T.V. emissions . . .	40 Mc/s	to above 300 Mc/s.

Mobile monitoring stations are particularly valuable for monitoring low-power stations and stations on frequencies above 30 Mc/s whose range is limited.

In addition to the use of equipment installed in a vehicle, certain measurements can also be made using portable equipment. Experience shows that separate mobile monitoring units specifically designed for selected types of measurement lend themselves more readily to operational use rather than a single vehicle equipped to make all classes of measurement.

* This Report was adopted by correspondence without reservation (see page 9).

2. Types of equipment.

It is considered undesirable to have to use special equipment for the mobile monitoring service and regular stock types of equipment with small dimensions, low weight and low power consumption are preferred. Since mobile equipment is subjected to vibration and shock, rugged construction, together with shock-mounting of components, is important. With the exception of some portable units the equipment is normally designed for operation at standard mains voltage and frequency.

It is preferred that instruments which are sensitive to temperature changes, particularly frequency standards which must be operated at relatively constant temperature, be designed to reach and maintain operating temperature in as short a time as possible so that continuous application of power will not be necessary or so that only limited circuits will require continuous power.

2.1 *Frequency standards and associated measuring equipment.*

The frequency standard should be capable of maintaining a frequency stability of one part in 10^7 per day or better, after nominal warm-up periods and under the operating conditions normally encountered in mobile service. To obtain high accuracy (± 5 parts in $10^8 \pm 1$ c/s) requires a comparison with frequency standards at least during 10 minutes daily.

As an alternative and provided short time stability is at least one part in 10^7 , continuous comparison of the frequency standard with frequency transmissions may be utilized while measurements are being made. It is desirable that the frequency measuring instruments be designed for direct measurement and display of the frequency of emissions. Oscilloscopes, panoramic display equipment and/or electronic counters are desirable additional equipment.

2.2 *Field strength measuring equipment.*

The extent to which field strength measuring instruments should be provided in a mobile monitoring station depends upon the purposes of the measurements. For regulation enforcement purposes, continuous coverage up to at least 1000 Mc/s is desirable. For obtaining propagation data, highly sensitive recorders operating on a fixed frequency have certain advantages although the instruments used for enforcement measurements may also be used for this purpose with some compromise in sensitivity and frequency stability.

This discussion will deal only with tunable continuous coverage instruments.

Wherever possible, field strength measurements should be made in an area where the signal field is relatively undisturbed by local reflections and re-radiation. Where there is strong dependence on location, measurements may be made in terms of median values, the recording being made continuously as a function of location or time.

The mobile station itself may contribute errors and the calibration includes aerial, receiver and recording equipment. It is desirable therefore that the equipment be portable so that measurements can be made away from the vehicle. To avoid directivity effects when measurements are made from the vehicle in motion, omnidirectional antennae are used. Since measurements of harmonic attenuation may involve comparatively weak signals, it is desirable that the field intensity meter be capable of the measurement of signal levels of the order of $1 \mu\text{V/m}$. The instrument should likewise be immune to over-loading from strong signals of 1 V/m or more. In order to attain satisfactory accuracies, considering that undisturbed fields are the exception at frequencies above 30 Mc/s, the errors contributed by the instrument itself should be less than ± 2 db. It is desirable that circuitry be incorporated for determination of peak and quasi-peak levels of pulsed emissions as well as for the average field intensity of amplitude and frequency modulated and similar transmissions.

2.3 *Bandwidth measuring equipment.*

Authorized bandwidths for stations assigned to the various V.H.F. and U.H.F. services vary from a few kc/s for communications services to several Mc/s for television broadcast services. Mobile monitoring stations should therefore, be equipped with spectrum analysers having very flexible characteristics including a sweep width of 20 kc/s or less for narrow band emissions and with the capability of displaying at least 5 Mc/s of spectrum at a time on certain broad band emissions.

The sweep rate should be variable from about 1 to 30 sweeps per second to permit optimum utility for various types of observations. Provision should be made for either linear or logarithmic display of signal levels and calibrated scales should be provided for direct measurement of level ratios.

Mobile measurements of bandwidth may be made by a frequency occupancy recorder for those types of modulation for which no measurement method of higher accuracy exists or when it seems impracticable to carry out such measurements in the mobile service because of the high technical expense involved. With telegraph signals for instance, the bandwidth can be determined from the signal element with the shortest rise time (see Doc. VIII/10 of Los Angeles, 1959). In the V.H.F. band, estimated bandwidths can also be read off the oscillograph screen of a panoramic set with a calibrated frequency scale. The measurement of bandwidth can also be made by a method of frequency analysis using a very narrow (± 100 c/s) filter to measure the magnitude of the spectrum components passing through the filter in relation to the carrier.

2.4 *Direction finding equipment.*

It is desirable that the monitoring receivers in a mobile installation also serve as receivers for the mobile direction finder. Light weight, compactness, high sensitivity, effective shielding, stability, robust construction and low power consumption are desirable features for mobile monitoring receivers. Furthermore, receivers for mobile monitoring should provide continuous tuning coverage of as wide a frequency range as possible. Accurate calibration of the order of 1 kc/s at 30 Mc/s and below, and 10 kc/s above 30 Mc/s is highly desirable. Accuracy of frequency resetting of the order of 1 part in 10^4 or better is also desirable. Although band-switching is preferable, plug-in R.F. units for different bands may reduce the circuit complexity.

The loop rotator should preferably be installed in the approximate centre of the roof of the vehicle with the loop socket extending through the roof and with the azimuth scale and rotating mechanism (usually a hand wheel) inside the vehicle at a convenient location. A number of plug-in-loops with different electrical characteristics will permit optimum results to be obtained over a wide range of frequencies.

Directional antennae are needed to extend the frequency range above the limits of loop antennae. Desirable characteristics are: high directivity, broad band frequency coverage, high gain, horizontal and vertical polarization and small size. Antennae types in use are horizontal and vertical dipoles, Yagi-beam, helical and rotatable H-type Adcock, while parabolic, horn type or corner-reflector antennae can be used above 300 Mc/s.

2.5 *Automatic monitoring of occupancy measuring equipment.*

Monitoring of spectrum occupancy at specified locations or along specified paths may be made in the mobile monitoring unit by means of a frequency spectrum recorder or by means of a panoramic adaptor.

The latter permits visual observations to be made over a relatively small band of frequencies while the vehicle is in motion.

2.6 Modulation measurement equipment.

It is desirable to provide facilities for measurement of percentage modulation of both amplitude and frequency modulated emissions. For the former a cathode ray oscilloscope with a wide band vertical amplifier usable up to 10 Mc/s or more is desirable. For measuring modulation deviation of F.M. emissions, an instrument capable of accurate measurement of carrier deviation over a range from ± 5 kc/s or less to ± 100 kc/s or more is desirable and should be capable of indicating instantaneous values. An overall accuracy of 5% or better is highly desirable. A cathode ray oscilloscope may be used as an indicator for the carrier deviation meter to permit measurements of instantaneous peaks of deviation of F.M. stations.

2.7 Television measuring equipment.

Measurements of the characteristics of the video waveform of television transmissions can be made with instruments specially designed for the purpose. Cathode-ray oscilloscope display of the various portions of the video signal is desirable in order that individual picture lines or segments thereof as well as individual synchronizing pulses may be observed. Provision should also be made for viewing the entire picture on a screen of adequate size to permit evaluation of the picture quality.

2.8 Power supplies.

To provide adequate power for large mobile monitoring units, a separate power unit mounted on a trailer may be used. An engine-alternator unit of 5 kW rating is usually adequate for this purpose.

For the smaller mobile monitoring units, an alternator of about 500 watts driven by the vehicle fan belt is a useful source of power.

Within the limitations imposed by the mobile monitoring service, most of the measurements listed in the first part of this report can be as readily performed with mobile as with fixed facilities, generally with little or no compromise in the desirable accuracy of the measurements. A major exception in the past has been with regard to frequency measurements, largely due to the difficulty of maintaining adequate accuracy and stability in the precision frequency standards which have been susceptible to shock and to temperature and line voltage variations. A further difficulty was the long period of time required for a standard to stabilize itself after the application of power or after receiving a hard mechanical shock. However, recently developed frequency standards designed particularly for aircraft navigational use largely avoid these difficulties.

3. Accuracies and limitations of measurement.

3.1 Frequency measurements.

Frequency standards are available which will maintain stability better than ± 1 part in 10^7 per day after a nominal warm-up period (two hours or less).

By means of frequency synthesizers or electronic counters, it is often possible to obtain direct measurements of the frequency of emissions without recourse to auxiliary interpolating instruments over a range of frequencies extending above 100 Mc/s. Transfer oscillator techniques may be used at much higher frequencies with interpolation between the transfer oscillator and the frequency standard being made with an electronic counter or other appropriate means. Measurement accuracies within the desirable limit of 5 parts in 10^7 may be accomplished under optimum conditions when the nature of the carrier is such that a precise zero beat may be obtained or where direct counting techniques may be used.

Under average field conditions accuracies of 1 part in 10^6 are readily obtained. On F.M. emissions, frequency averaging techniques with an electronic counter will provide an equal order of accuracy.



Using a discriminator, the accuracy depends upon the accuracy of the local standard used and upon the deviation of the F.M. signal; accuracies of the order of about 5 parts in 10^4 of the deviation to be measured are attainable.

For frequencies above 100 Mc/s frequency dividers or frequency conversion techniques may be used to permit use of the lower frequency interpolators or counters in obtaining measurements approaching or equaling the accuracy obtainable at lower frequencies.

3.2 *Field strength measurements.*

The accuracy of field strength measurements above 30 Mc/s is limited not so much by the instruments themselves as by the local conditions which tend to distort the electromagnetic field so that a considerable variation in field strength over relatively short distances may be expected. This problem may be alleviated to some extent by making several measurements at each measuring location moving the antenna a few feet horizontally between measurements. Under average conditions, even when appropriate precautions are taken to ensure optimum accuracy, the accuracy cannot be depended upon to be better than ± 2 db. If large numbers of measurements are made as functions of time, location or distance, etc., the statistical evaluation will yield values of the quasi-maximum, quasi-minimum and median values with an accuracy of about ± 3 db or better depending somewhat on the distribution of field strengths. A major limitation of portable or mobile field strength meters is the limited sensitivity, particularly at the higher frequencies. In the lower portion of the spectrum, up to several megacycles, atmospheric noise is likely to be a limiting factor on the usable sensitivity, while at higher frequencies the noise introduced by the instrument itself becomes important. Under average field conditions and depending upon the frequency involved, the minimum field which may be measured with portable instruments with the accuracies mentioned above, will range from about 2 to 100 $\mu\text{V/m}$ in the frequency range from 10 kc/s to 1000 Mc/s.

3.3 *Bandwidth measurements.*

A major limitation of available spectrum analysers, whether for fixed or mobile use, is the problem of obtaining a high degree of resolution and at the same time keeping the sweep rate high enough to provide for essentially continuous coverage of the band of frequencies under observation. The best resolution can only be obtained at a slow sweep rate while a higher sweep rate is desirable in observing infrequent transients of short duration. This problem may be somewhat alleviated by increasing the period of time over which observations are made and by use of a cathode ray tube having long persistence. The problem of providing for a very wide range of sweep widths can be met by using two spectrum analysers, one designed for high resolution and with a maximum sweep width of about 100 kc/s and the other designed for much greater sweep width (up to 5 or 10 Mc/s) but with proportionately poorer resolution. Accuracy of measurement of relative signal levels depends upon a number of factors, including flatness of response of the instrument over the frequency band swept, accuracy of scale calibration, the resolution, viewing conditions, etc.

Analyser units are practicable which read to within 10% of the expected amplitude on signals whose individual spectrum components are spaced at intervals no closer than the intervals of resolution for which the analyser is adjusted.

When using a spectrum recorder for the determination of bandwidth, the threshold sensitivity of the receiver must be adjusted to a value which corresponds to the lowest sideband component that it is desired to measure in relation to the carrier strength. The field strength of the signal, its constancy with regard to time and the sensitivity of the receiver will affect the accuracy of the bandwidth measurement. Discrimination between two frequencies depends upon the filters used, the tuning rate of the receiver and the reduction gear between receiver and recorder. In equipment in use in Federal Republic of Germany, the filters have a bandwidth of ± 40 c/s and the

minimum frequency range that can be recorded when spread over the whole width of a 20 cm recording-strip is 2 kc/s. Panoramic equipment of the German monitoring service has a resolving power of about 400 c/s for frequencies above 30 Mc/s.

3.4 *Direction finding.*

A major limitation of loop direction finders is their polarization error in the presence of signals with significant skywave components. A further serious limitation of a direction finder which depends upon the direction of arrival of the wave front is the likelihood of local reflections or re-radiation from nearby objects such as buildings, transmission and telephone lines, etc. In an area where the wave is relatively free from distortion due to local conditions, where the path of arrival is essentially horizontal (vertically polarized wave) and taking into account possible errors introduced in orienting the direction finder azimuth scale, accuracies of the order of ± 5 degrees with vehicle mounted loop direction finders are typical, with somewhat greater accuracy at frequencies below about 5 Mc/s. However, where the wave has been distorted by local conditions or where skywave components are present, bearing nulls are likely to be obscured or to deviate widely from the true direction of the emission source.

Where the ground wave is predominant (i.e. the ratio of ground-wave to reflected waves being at least 6 db) direction finding loops may be used in the frequency range 10 kc/s to 30 Mc/s. The accuracy obtained depends upon the signal level and the equipment used.

Typical values for a d/f null 1° wide are:

10 kc/s	—50 $\mu\text{V/m}$,
1000 kc/s	—15 $\mu\text{V/m}$,
20 Mc/s	—10 $\mu\text{V/m}$.

For the bearings of horizontally polarized signals (groundwave) at frequencies above 30 Mc/s, Yagi-beam antennae may be used in a maximum signal d/f method with an angular width of bearing indication of $\pm 15^\circ$.

For measurements made from a vehicle in motion, no proper bearing seems possible because of multiple reflections from nearby objects. However, when equipped with a visual indicator, mobile d/f sets will allow determination of a median value of the varying indications and hence yield an approximate direction.

3.5 *Monitoring of occupancy of radio frequency spectrum.*

The accuracy obtainable from a frequency spectrum occupancy recorder depends upon the receiver and the overall calibration. Equipment used in the Federal Republic of Germany has the following characteristics:

- Sensitivity better than 1 $\mu\text{V/m}$.
- Accuracy of field strength indication ± 3 db at angles of incidence below 60° .
- Frequency stability of receiver, ± 5 parts in $10^5 \pm 40$ c/s (where ± 40 c/s is the bandwidth of the filter).
- Accuracy of reading time markers, ± 1 minute or ± 30 seconds.
- Adjustable maximum frequency spread on the recording strip by choice of appropriate gear reduction, 100 c/s per mm. When monitoring above 30 Mc/s by means of panoramic sets the resolving power may be about 400 c/s.

3.6 *Percentage modulation.*

Cathode ray oscilloscopes with the desirable characteristics for measurement of percentage modulation of amplitude modulated signals are available. Accuracy of such measurements can usually be maintained within $\pm 5\%$. For measurement of carrier deviation instruments are available which meet the desirable characteristics listed in § 2.6. Self contained calibrators are provided to maintain an instrument accuracy better than 5% .

3.7 *Television measurements.*

Instruments are available for performance of all desirable television measurements and observations mentioned in § 2.7. Measurement accuracy of the various instruments in most cases approaches or equals that of measurements which can be performed at a fixed location. Comparative level measurements of components of the composite video waveform, for example, can usually be made with an accuracy of 5 to 10%.

Measurements and observations which may be performed with the equipment installed in a mobile television enforcement unit in U.S.A. include—

- Frequency measurements of television station carriers (including chrominance sub-carrier frequency of color transmissions).
- The precision frequency measuring equipment covers a frequency range of 20 to 1000 Mc/s with an accuracy capability under optimum conditions of five parts in 10⁷.
- Measurements of synchronizing pulse waveform and timing video waveform and of colour video phase relationships.
- Checking of video levels with respect to synchronizing pulse levels.
- Measurements of bandwidth of television emissions including observations of spurious emissions at all frequencies between 54 Mc/s and 890 Mc/s.
- Percentage of modulation measurements of visual and aural transmissions.
- Measurements of audio distortion and noise level.

REPORT No. 169 *

FREQUENCY MEASUREMENTS AT MONITORING STATIONS

(Question No. 145 (VIII))

(Warsaw, 1956 — Los Angeles, 1959)

Question No. 145 (VIII) seeks information on the desirable ratio of the error of frequency measurement to the permissible tolerances of emission and the accuracy required for various classes of service extending up to, in certain cases, at least 3000 Mc/s. This Question replaced an earlier Question No. 89. Report No. 67 summarized very briefly the information which had been presented up to that time on measurements above 50 Mc/s. At Warsaw, the necessary accuracy of frequency measurements of emissions in various categories, both at fixed and mobile monitoring stations for frequencies above 50 Mc/s was added to the Table of Recommendation No. 20 which was therefore replaced by Recommendation No. 180, which in turn was replaced by Recommendation No. 322.

Information on equipment, accuracy of measurement and methods is contained in Docs. 35, 37, 41, 117 and 427 of Warsaw 1956, and more recently in Docs. VIII/2, VIII/4, VIII/12, VIII/15 and VIII/19 of Los Angeles, 1959. The information available at present may therefore be summarized as follows:

1. 1.1 With regard to measurements above 50 Mc/s, the frequency measuring equipments of the individual countries differ so much that it is only possible to comment generally upon them. Administrations in general prefer to make measurements with nearly the same equipment as that

* This report which replaces Report No. 67, was adopted by correspondence without reservation (see page 9).

which they use for frequency measurements below 50 Mc/s. The extension to a higher frequency range is effected by the use of harmonics of either a secondary standard or a stable transfer oscillator or frequency synthesis method providing a single tunable frequency. All equipments use direct reading dials in conjunction either with electronic counters or with visual indicators such as pointer instruments or oscilloscopes.

1.2 With regard to the desirable ratio of the error of frequency measurements to the permissible tolerance and the use of statistical methods of evaluation, it may not be necessary or even desirable to define the accuracy of frequency measurements in terms of a statistical calculation for enforcement purposes or for reporting, if necessary, frequency measurements of stations to the I.F.R.B. Frequency measurements made on a statistical basis may be useful for inter-comparing frequency standards and in such cases they should be made to the greatest possible accuracy. It would appear that to treat a number of measurements to a statistical evaluation, it should be presumed that the signal measurement did not itself shift in frequency between measurements or that the various measurements were made simultaneously at different monitoring stations or on different measuring equipments but such is not usually the case.

1.3 When an individual measurement of radio station is made, its accuracy can be estimated from a knowledge of all of the factors (except perhaps that of Doppler effect) which produced the error. The sources of error which should be known to the measurer, are: the maximum error in the frequency standard of reference; the maximum instability error of the transfer oscillator and the error of setting that oscillator to zero-beat with the signal. Inasmuch as the direction of errors, other than that of the reference standard, will not usually be known, the error of measurement should be estimated as if they were all in the same direction after allowing for any known error of the reference standard.

1.4 It is considered that a conservative ratio of error to tolerance as applied to the majority of frequency measurements is to be preferred over a ratio difficult to obtain. With a conservative ratio, the measuring equipment may be operated well within its capabilities with a greater degree of assurance that all measurements meet the desired minimum accuracy.

1.5 The ratio of 1 to 10 given in Recommendation No. 322 between the error of measurement and the tolerance appears to be a reasonable general criterion to retain for the minimum accuracy desired when measurements are made to assure compliance with tolerance requirements. (The absolute accuracy of the secondary standard of a mobile frequency measurement installation cannot well be made much better than 5 parts in 10^8 . Even with such a high accuracy, a ratio of 1 to 10 between the error of measurement and the permissible tolerance of a television emission is not always attainable. Nevertheless a ratio of 1 to 5 between the error of frequency measurement and the permissible tolerance of the carrier would be very desirable, with a series of at least three individual measurements taken on the same emission.) However there is apparently a practical limit to the possible increase in measurement accuracy caused mainly by errors introduced by sky-wave propagation of frequency standard reference signals. Therefore this question may have to be reconsidered at a future date in the light of decisions reached in any recommended changes in tolerances resulting from work under Question No. 1 (I) § c and Study Programme No. 3, also with regard to any improved accuracy of measurement procedures arising from increased accuracy of reference standards such as the possible future use of atomic frequency standards by monitoring stations or elimination of the Doppler effect of standard frequency stations operating on very low frequencies.

It may be pointed out that some frequency measurement e.g. measurements made in connection with frequency occupancy data may not require the accuracy set forth in Recommendation No. 322.

2. With regard to § 2 of Question No. 145 (VIII) on the accuracy of frequency measurements which can be accomplished at monitoring stations the following statement may be made:

2.1 Standard frequency transmissions are available with a claimed accuracy, as transmitted, of better than ± 1 part in 10^8 . Secondary frequency standards which can be maintained to an accuracy of better than ± 1 part in 10^7 are available for both fixed and mobile monitoring stations. Where ground wave transmissions from standard frequency stations are available, the secondary standards may be maintained to approximately 1 part in 10^8 .

2.2 Table I lists the accuracy of measurement of various classes of emission which can be attained under optimum conditions at fixed and mobile monitoring stations.

n is the integer equal to or immediately above one thirtieth of the measured frequency in Mc/s.

TABLE I
*Accuracy of measurement attainable under optimum conditions at fixed
and mobile monitoring stations*

Class of emission	Fixed stations	Mobile stations
A0, A3, A3b	$\pm 2.5 \times 10^{-8} \pm 0.5 n \text{ c/s}$	$\pm 4 \times 10^{-8} \pm 0.5 n \text{ c/s.}$
F1, A1	$\pm 2.5 \times 10^{-8} \pm 0.5 n \text{ c/s} \pm 2.5 \text{ c/s}$	$\pm 4 \times 10^{-8} \pm 0.5 n \text{ c/s} \pm 2.5 \text{ c/s.}$
F1 MUX	$\pm 2.5 \times 10^{-8} \pm 0.5 n \text{ c/s} \pm 10 \text{ c/s}$	$\pm 4 \times 10^{-8} \pm 0.5 n \text{ c/s} \pm 10 \text{ c/s.}$
F3, using discriminating equipt.	$\pm 2.5 \times 10^{-8} \pm 100 \text{ c/s}$	$\pm 4 \times 10^{-8} \pm 100 \text{ c/s.}$

2.3 The error introduced by an electronic counter can be held to ± 1 count. If a one second gate period is used for measurements at 10 Mc/s the one count error will result in a counter error of only one part in 10^7 . The same percentage accuracy will be obtained using a 10 second gate at 1 Mc/s. Therefore considering the possible errors from the standard and the frequency counter, an overall accuracy of ± 2 parts in 10^7 is obtainable. The above accuracies are for measurements of unmodulated continuous wave signals. The methods of measurement in general use result in the determination of the instantaneous frequency as received. Therefore, when measuring distant stations, due regard must be given to frequency shifts caused by varying propagation conditions (e.g. Doppler effect). Errors due to the use of a stable transfer oscillator can be reduced to a negligible amount by the use of an oscilloscope for the zero-beat adjustment.

2.4 For emissions having a discrete component at the assigned frequency, which can be identified, the accuracy is practically the same as for unmodulated transmissions. For emissions having discrete components which can be identified at other than the assigned frequency, the accuracy is further limited by the accuracy with which the displacement is known.

2.5 Under conditions of fading, and where the measurement is made using a pattern on the screen of an oscilloscope, the measurement is performed only when there is sufficient signal strength, e.g. A1 stations are measured only during on-keyed conditions and not during a field strength minimum period. Under these conditions the accuracies listed in Table I can be obtained.

2.6 Under conditions of interference between two amplitude-modulated stations, the frequency of the weaker station can still be measured with the accuracy indicated in Table I, if the carriers of the wanted and unwanted stations are spaced by at least 40 c/s. With a field strength ratio between the wanted and the unwanted stations of 1 to 1, good measurements may be made with the accuracy indicated in Table I, when the carriers are only spaced by 12 c/s. For a field

strength ratio of 2 to 1, the minimum frequency spacing at which good results are obtained is 2 c/s. These high accuracies of measurement are made possible, even under conditions of interference by other stations, by visual observation of the Lissajous patterns produced on the oscilloscope screen by combining the heterodyne beat between the received signal and the comparison frequency and a fixed standard frequency of 1000 c/s. By receiving mutually interfering stations on a d/f equipment, their ratio of signal strengths at the receiver input can be improved, thus making possible measurements with the accuracies shown in Table I at smaller carrier spacings.

2.7 Two interfering frequency modulated stations can be measured for unfavourable field strength ratios when the frequency separation between their carriers is at least 2 to 3 kc/s. The measurements are taken during periods of no modulation by heterodyning the wanted carrier with the comparison frequency and observing the results on a panoramic display screen. The accuracy will then be within ± 500 c/s. Here too, by employing a d/f technique the received signal strength of the unwanted station may be attenuated far enough so as to attain the accuracies indicated in Table I.

2.8 In the case of carrier instability, measurements can be made either as a series of measurements of instantaneous frequencies employing the oscilloscope method or in the case of rapid variations of the carrier frequency, the centre frequency can be determined by means of a discriminator equipment, or a panoramic adaptor, resulting in an accuracy of measurement of the edge frequencies of about ± 50 c/s.

2.9 Keyed carriers can be measured by the oscilloscope method with the accuracies listed in Table I.

2.10 In the case of suppressed carriers, individual frequencies of the kind listed under § 2.5, 2.6, 2.7, 2.8 and 2.9, that are contained in the transmission spectrum, can be measured with the accuracies listed in those paragraphs. In the case of a carrier not completely suppressed, the measurement can be made with the accuracy indicated in § 2.6.

3. 3.1 With regard to § 3 of Question No. 145 (VIII) concerning equipment and methods preferred for the measurement of frequency of F.M. emissions, Doc. VIII/4 of Los Angeles, 1959 states that in the U.S.A. the carrier frequency of an F.M. transmitter may be measured by any of the usual methods during intervals of no modulation. When modulated, it has been the practice in the United States to measure the average frequency by means of a frequency counter. If the frequency tolerance applicable to the assigned carrier frequency is to be applied in such measurements of a frequency modulated signal, it must be taken into account that the average frequency will not equal the unmodulated carrier frequency unless the frequency excursion above and below the carrier frequency is perfectly symmetrical.

The contribution from the Federal German Republic (Doc. VIII/2 of Los Angeles, 1959) states that emissions employing frequency shift keying are measured in the same way as amplitude modulated emissions with keyed carrier. The accuracy attained is as shown in Table I. Emissions frequency modulated by speech or music are measured by heterodyning them with an appropriate selectable frequency derived from the secondary standard or synchronized by the same. The resulting beat frequency is fed to a discriminator equipment with an adjustable linear operating range so that it can be adapted to the deviations of the respective emissions up to a maximum deviation of ± 100 kc/s. The accuracy attained is equal to that shown in Table I.

3.2 With regard to § 3 of Question No. 145 (VIII), concerning equipment and methods preferred for frequency measurements of amplitude-modulated emissions at monitoring stations, the U.S. Administration states (Doc. VIII/4 of Los Angeles, 1959) that no special problems arise regarding the measurement of emissions of television stations with equipment available at present and usual methods of either direct, or indirect transfer oscillator measurement, except for U.H.F. television stations. It is at present difficult in the United States, outside a laboratory having

direct access to a primary frequency standard, to approach the desired accuracy for measurements of U.H.F. television stations operating with a ± 1000 c/s tolerance. Measurement of the aural frequency-modulated carrier for stations in the U.S.A. involves no particular problem since the tolerance is specified as its separation from the video carrier and the inter-carrier beat can be directly measured on an appropriate counter to within a few c/s.

In Doc. VIII/2 (Federal German Republic) of Los Angeles, 1959, it is stated that for measurements of television stations working in precision offset, the high-accuracy secondary standard used at fixed monitoring stations is automatically and continually compared and adjusted with respect to a standard frequency of 1000 c/s. The accuracy of the local secondary standard is held to within to a ± 5 parts in 10^9 relative to the primary standard. For measurements at mobile stations, the secondary standard is held continuously in operating condition. When a car is stationed at a location where the primary standard frequency on lines is available, the mobile secondary standard is automatically adjusted. After arriving at a measurement site in the open, a comparison is first made between the mobile secondary standard and a standard frequency emission on long waves (in the band between 60 and 200 kc/s) for a period of at least 10 minutes using an oscilloscopic method, before a measurement is taken. The accuracy of the mobile secondary standard can thus be held to within ± 4 parts in 10^8 relative to the primary standard emission.

REPORT No. 170 *

FIELD STRENGTH MEASUREMENTS AT MONITORING STATIONS

(Study Programme No. 102 (VIII))

(Los Angeles, 1959)

Study Programme No. 102 (VIII) seeks information on the preferred equipment and methods to be used at monitoring stations for the measurement of field strengths for propagation studies, for the measurement of field strengths of certain types of emission, measurement in the presence of noise and interference and measurement at a distance of the relative levels of fundamental and harmonics of an emission.

Doc. VIII/6 of Los Angeles, 1959 summarizes the preferred methods of making measurements for propagation studies in Germany and comments on other aspects of the Study Programme.

Doc. VIII/22 of Los Angeles, 1959 comments on the work which is being carried out in the United States of America to obtain propagation data for frequency allocation planning and for establishment of station separation standards. An automatic method of analysing field strength records is described.

Doc. VIII/20 of Los Angeles, 1959 deals with preferred methods of measuring field strength at monitoring stations in the U.S.S.R., including methods of calibration, recording, analysis of data, etc. The measurement of field strength of special types of emission is also considered.

* This Report was adopted by correspondence without reservation (see page 9).

Comments on particular aspects of Study Programme No. 102 (VIII) are also given in Docs. No. VIII/16 and VIII/8 (Los Angeles) from the Administrations of Japan and Czechoslovakia respectively. The latter paper deals especially with the calibration of field strength measuring apparatus.

In considering this Study Programme, reference should also be made to other studies of the C.C.I.R. on general aspects of field strength measurement which have resulted in a number of Recommendations and Reports. (In particular, Recommendation No. 22 and Report No. 138.)

SUMMARY OF CONTRIBUTIONS

1. Doc. VIII/6 (Federal Republic of Germany) of Los Angeles, 1959.

1.1 In regard to Part I of the Study Programme, the preferred equipment and preferred methods for measuring the field strength of emissions for propagation studies at monitoring stations in the Federal Republic of Germany are as follows:

1.1.1 *Method of measurement.*

When carrying out field strength measurements for propagation studies, in most cases it will not be necessary to calibrate the equipment very frequently if the metering equipment or the receivers with calibrated antennae are working under the same operating conditions for extended periods of time. The type of antenna for the field strength measurement is chosen according to the specific case. For measurements in the low, medium and high frequency bands often a stub antenna with impedance matching transformers [1] or wideband stub antenna with constant feed impedance [2] is used. In some particular cases, however, directional antennae designed for a single frequency or a small band of frequencies are used. Field strength measurements on VHF and UHF are best made by means of wideband dipoles [3] or special directional antennae (e.g. parabolic reflectors).

In certain cases, e.g. measurements for the purpose of HF propagation studies, one may require to obtain a general survey of the overall propagation conditions over a band of frequencies. The present method of automatic monitoring of spectrum occupancy will yield only a very rough impression of the propagation conditions, since it does not discriminate between the various path directions and cannot make allowance for the difference in distances between the transmitting stations and the receiver location. Therefore, it seems expedient to make short observation records lasting about 10 minutes, over the entire high-frequency band at intervals of about 90 minutes, of stations known to be on the air for 24 hours a day, appropriately chosen so that the interesting ranges of frequencies and distances are well represented.

1.1.2 *Measuring and recording equipment.*

The test equipment may, consist of the antennae mentioned above under § 1.1 in conjunction with special field strength meters. In the Federal Republic of Germany such field strength meters are:

- for the band between 10 and 100 kc/s,
- for the band between 100 kc/s and 30 Mc/s,
- for the band between 20 Mc/s and 1000 Mc/s.

The measuring equipment may also consist of the antennae mentioned above under § 1.1.1 and communications receivers that are specially stabilized.

The recording can be effected by means of a level recorder (when used in mobile operation preferably of the shock-proof type) [4]. In fixed stations the direct recording of the statistical

distribution of the field strength variations by automatic distribution counters is recommended [5]. A new method of field strength recording equally usable in fixed and mobile stations makes use of a magnetic tape equipment [6]. In this method the d.c. voltage variations of the a.v.c. line, representative of the field strength, are transformed to audio frequencies (50-300 c/s) by means of an oscillator controlled by a reactance valve and used to modulate the amplitude of a low frequency carrier (about 5 kc/s).

1.1.3 *Total frequency range.*

It is considered that measurements for propagation studies may be required in the frequency range between 10 kc/s and 20 000 Mc/s. In Germany, however, the higher frequency bands are not continually covered with the existing receiving equipments, though special receivers for selected bands of frequencies are available.

1.1.4 *Calibration.*

A good practice is to have the field strength meters for use on frequencies below about 30 Mc/s calibrated initially on a loop aerial. The loop is placed at a small defined distance from a Lecher line which is terminated with a resistance equal to its surge impedance and which can be coupled to a radio frequency power source. If the current flowing in the Lecher line is known, the field intersecting the loop can be computed.

For determining the effective height of an antenna the receiver input signal is compared with the indication of a calibrated field strength meter. The effective height of an antenna thus computed for a specific frequency may be regarded to be indefinitely constant. However, the ratio between the radio frequency input signal and the a.v.c. voltage (relative field strength indication) of the receiver must from time to time be calibrated by means of a signal generator [7]. (A simple method of calibrating receivers is described in Doc. VIII/8 of Los Angeles, 1959.)

For mobile VHF and UHF field strength metering equipments special calibrated signal generators can be used, with a defined field being produced by a signal generator the power for which is supplied by batteries. In this case the field strength is calculated from the RF current flowing in the feed-point of the half-wave dipole employed [7].

1.1.5 *Evaluation.*

In recording field strength it is often desirable to know the upper-decile (F_{10}), the median value (F_{50}) and the lower decile (F_{90}), values. The best form of presentation of measurements on single frequencies for propagation studies is felt to be the indication of the median value (F_{50}) and the standard deviation in db relative to 1 μ V/m.

The data required for the study of the propagation conditions over specific paths can usefully be presented in the form indicated in Figs. 1 and 2, of Doc. VIII/6 of Los Angeles, 1959, thus providing a clear survey on the propagation conditions over a full month. The specimens shown in Figs. 1 and 2 for the paths New York-Germany and Washington-Germany clearly indicate the variation in the usable frequency range over a period of 24 hours. In this representation, the quality of reception is evaluated in three classes indicated by the density of the points placed on the diagram [8].

1.2 With regard to § 2 of Study Programme No. 102 (VIII) the following observations are proposed for propagation studies.

1.2.1 *For frequencies below 300 kc/s.*

Field strength measurements at great distances from the transmitting stations, particularly when transmitter and receiver are symmetrically located relative to the equator.

1.2.2 *For frequencies from 300 to 3000 kc/s.*

Field strength measurements at locations of different geographical latitude, when transmitting station and receiving point are spaced up to and above 2000 km. These measurements serve the ionospheric propagation studies in a similar way to those which have carried out for some time by the E.B.U.

1.2.3 *For frequencies up to 5 Mc/s.*

Field strength measurements up to distances of 1000 km for absorption studies.

1.2.4 *For frequencies between 5 Mc/s and 30 Mc/s.**

Field strength measurements over great distances including paths near the polar regions and between stations located symmetrically relative to the equator.

1.2.5 *For frequencies between 30 Mc/s and 300 Mc/s.*

Field strength measurements over distances between 0.7 and 1.5 times the optical distance and distances beyond 400 km over average terrain and over obstructed paths including mountain ridges. All these measurements should be carried out according to the requirements of the appropriate Study Groups of the C.C.I.R., by the international monitoring stations.

1.3 With regard to § 3 of Study Programme No. 102 (VIII) for the field strength measurements of emissions with continuous, interrupted, or reduced carriers as well as of other types of signals, methods and equipments should be employed that are suitable for all classes of emission. For this reason the following practice has been accepted in the Federal Republic of Germany.

1.3.1 For the measurement of the field strength of emissions with interrupted carriers a special circuit is employed by which the quasi-peak value can be measured (1 ms built-up time, 600 ms decay time). When this method fails (e.g. in the case of keyed pulses) because of too long a build-up time, the measurement can be made by the substitution method using a cathode ray oscilloscope.

1.3.2 When measuring the field strength of emissions with reduced carriers,

- the reduced carrier can be measured separately by means of a standard-type field strength meter of very narrow bandwidth (e.g. 100 c/s). For a continuous recording of the reduced carrier, automatic frequency control (a.f.c.) should be provided.
- the total emission can be measured by means of a field strength meter of wider bandwidth, the circuit time constants of the meter being chosen to give average values of field strength. This means, that the indication of a carrier modulated 80% should not deviate by more than 5% from the unmodulated carrier value.

2. Doc. VIII/16 (Japan) of Los Angeles, 1959.

This document states that, in Japan, strength measurements of interrupted carrier emissions at monitoring stations are made in accordance with Recommendations No. 61 ** and 112 **. Recommendation No. 61 ** considers that telegraph modulation can be regarded as a special form of pulse transmission, while Recommendation No. 112 ** states that the field strength of such an emission should be expressed by the r.m.s. value of the level corresponding to the peak level of the pulse.

Accordingly, in instruments used in Japan, the time constants of the detector circuit are chosen so that there is a rapid build-up at marking and the slowest possible discharge at spacing.

* The original text of the document submitted by the Federal Republic of Germany has been modified in conformity with the recommendations of Study Group VI.

** See Report No. 138.

These characteristics should apply even at very low keying-speeds. If the discharge time of the detector circuit is too long, the field strength will not be indicated correctly in the presence of rapid fading. Time constants of 500 microseconds charge and 1 second discharge have therefore been adopted, but the charge time actually depends on the inertia of a pen recorder or the indicator of an output meter.

For measurements of reduced carrier, it is considered desirable that the expression of field strength in Recommendation No. 63 * be followed, since the field varies greatly with input modulation levels. For this class of emissions some data have been obtained for the measurement of field strength of a suppressed carrier, SSB, emission, made in accordance with Recommendation No. 63 *. The result shows that the field strength with suppressed carrier modulated by speech approximates fairly closely to the measured value of the field strength of the suppressed carrier modulated by a single tone if the time constants of the detector circuit are large compared with the intervals of speech and measurements are made when there is little fading.

It is concluded, therefore, that the field strength of suppressed carrier SSB emissions can be measured also by the use of the field strength measuring equipment for amplitude modulated emissions.

Referring to § 4 of Study Programme No. 102 (VIII), when disturbances and heterodyne interferences are encountered the field strength measurements are made by means of panoramic equipments and employing the substitution method. The maximum resolution of the panoramic equipment sets the limit of discrimination between two interfering stations. (Some examples of the resolution characteristics of the equipment are presented in the contribution of the Federal Republic of Germany (Doc. VIII/2 of Los Angeles, 1959) to Question No. 145 (VIII)).

Measurement of emissions in the presence of interference from adjacent frequencies is made by a panoramic unit attached to the equipment, so that any interfering emission may be separated from the required signal and the field strength with interrupted carrier, which is indicated on the screen of the cathode ray tube, may be obtained using the comparison signal of the equipment for calibration purposes.

3. Doc. No. VIII/22 (U.S.A.) of Los Angeles, 1959.

This document states that continuous field strength measurements over fixed transmission paths are made to obtain propagation data required for frequency allocation planning and for the establishment of station-separation standards. These measurements have been largely concentrated in the 540 to 1600 kc/s, 30 to 216 Mc/s and 470 to 890 Mc/s bands. However, measurements have also been made at selected frequencies in the 1600 kc/s to 30 Mc/s range for limited periods of time.

Report No. 138 prepared by Study Group V, contains much material concerning field strength measurements and measuring instruments which is pertinent to Study Programme 102 (VIII).

A typical field strength recording installation consists of a suitable antenna, a sensitive receiver with appropriate bandwidth for the emission to be recorded and includes provisions for converting the received signal into a corresponding direct-current for operation of an associated d'Arsonval type recording milliammeter; a radio frequency standard signal generator for use in calibrating the receiver in terms of radio frequency voltage input levels is also used. In order to ensure minimum frequency drift, the conversion oscillators in the receivers are controlled wherever possible by quartz crystals. Stabilization of the alternating current line voltage is provided by primary voltage regulators. Further protection against fluctuation is obtained by stabilization of the direct current voltages applied to certain critical circuits. Minimization of changes in receiver gain is accomplished by careful design of receiver circuitry, by the aforementioned voltage stabilization and by operating the equipment at an essentially constant temperature. This latter goal is achieved by a combination of thermostatically-controlled exhaust fans and heaters in the recording booth.

* See Report No. 138.

The calibration process involves two phases:

- determination of the effective height of the recording antenna — taking into account losses in the connecting transmission line;
- daily, or more frequent, receiver calibration to eliminate possible errors due to progressive changes in sensitivity or overall amplification.

Measurements in the broadcast bands consist of continuous field strength recordings made over fixed paths from AM, FM and television broadcast stations in regular operation in various parts of the U.S.A.

In the 540 to 1600 kc/s broadcast band, continuous recordings have been made during the past two eleven-year sunspot cycles. These recordings are analysed by obtaining hourly median values of field strength from the record charts, which values are then plotted as scatter diagrams of field strength against monthly groups. From these diagrams monthly median values may be obtained. Particular attention is given to the second hour after sunset for the mid-point of the path between transmitter and receiver. Values for other hours and for other than median levels may be obtained in a similar manner.

V.H.F. and U.H.F. field strength measurements (FM and TV broadcast stations) have been in progress since 1946 at various locations throughout the U.S.A. over paths having lengths from 60 to 1000 km (38 to 633 miles). The type of antennae used depends on the frequency range involved and other factors. For frequencies below 30 Mc/s vertical antennae the length of which is short compared with one quarter wavelength have proved satisfactory. Between 30 Mc/s and 216 Mc/s, horizontal halfwave dipoles at a standard elevation of 10 m (30 feet) are commonly used. For frequencies in the UHF television range, it has been found that directive antennae are necessary for recording weak transmissions to obtain adequate signal input to the receiver. Corner-reflector type antennae which provide a gain of 10 db or more over a halfwave dipole antenna are readily adaptable to this application.

In the past, analysis of the records was performed manually, a time-consuming and tedious operation. A new analysis system has been devised which eliminates much of the human effort. This system is based upon a method of recording periodic samples of signal strength, rather than a continuous registration of signal levels, using regular equipment with simple modification. At each recorder a time switch operated by a synchronous motor is arranged so that a contact is closed once every two minutes for a duration of about five seconds. This contact is inserted in an appropriate circuit in the receiver where it will cause the recording instrument to respond by drawing an inked line with each operation of the switch. The recorder chart will then show a series of lines. When operated at the usual speed of 75 mm (three inches) per hour, the paper will show 10 lines per inch each having an amplitude with a known relationship to signal strength. It has been found that 30 samples per hour will yield adequate accuracy for most applications. After the recordings have been made, the charts are forwarded to the processing centre for analysis on equipment specially constructed for this purpose. This equipment consists of a photoelectric cell arrangement for counting the hourly number of samples having amplitudes exceeding a pre-set level, while the chart paper moves through an appropriate optical system. Hourly numbers of samples at each level are automatically counted and printed by means of an electrical counter and a sequential count printer. These numbers may be directly converted to equivalent percentages of time for all indications of signals exceeding given levels. The data are thus available in hourly values from which monthly and yearly distribution curves may be plotted showing diurnal and seasonal variations of field strength at any percentile levels.

BIBLIOGRAPHY

1. FÖHLMANN. Ein neues Feldstärkemessgerät (A new field strength meter). *Rhode und Schwarz-Mitteilungen* (in preparation).
2. TROOST. Neuzeitliche Adcock-Peiler (Modern Adcock d/f equipments). *Mitteilungen aus dem Telefunken Laboratorium*, Vol. 2, No. III; Neuentwicklung von Kurzwellen-Adcock-Peilern (New development of h.f. Adcock d/f equipments). *Telefunken-Zeitung*, Vol. 25, No. 94 (March 1952).
3. GREIF, K. Breitbandantennen für Vertikalpolarisation (Vertically polarized broadband antennae). *Rhode und Schwarz-Mitteilungen*, 1, 4-5 (1952).
4. SCHNEIDER, J. Der Enograph (The Enograph recorder). *Rhode und Schwarz-Mitteilungen*, 4, 222 (1953).
5. GROSSKOPF, J. Grundlagen der Feldstärke-Messtechnik und Messverfahren I (Fundamentals of the field strength measuring equipments and measuring methods I). *Der Fernmelde-Ingenieur*, 7 (1953).
6. V. RAUTENFELD, F. THISSEN, P. and GRAMATKE, B. Die Speicherung von Messgrößen auf Magnettonband (The recording of data on magnetic tape). *Rundfunktechnische Mitteilungen* (in preparation).
7. GROSSKOPF, J. Grundlagen der Feldstärke-Messtechnik und Messverfahren II (Fundamentals of the field strength measuring equipments and measuring methods II). *Der Fernmelde-Ingenieur*, 8 (1953).
8. PLAGE and OCHS. Das Funkwetter im Monat Januar 1958 (Radio propagation conditions in January 1958). *Fernmeldepraxis*, 3, 116 (1958); *ibid.* Beobachtungen des Übertragungsfrequenzbereiches für Kurzwellen und ihre Auswertung (Observation and analysis of the operational transmission frequency range on h.f.). *Fernmeldepraxis* (in preparation).

REPORT No. 171 *

IDENTIFICATION OF RADIO STATIONS

(Question No. 187 (VIII))

(Warsaw, 1956 — Los Angeles, 1959)

This report summarizes the contributions to, and the discussions on, the identification of radio stations at the IXth Plenary Assembly. It also retains that material from Report No. 91 which was considered by Study Group VIII to have an application to:

- further studies concerning Question No. 187 (VIII), and
- the adoption by administrations and operating agencies either of the provisions of Recommendation No. 323 or of other methods of identification and operating procedures relating thereto as discussed in this Report.

1. In the interval between the VIIIth and IXth Plenary Assemblies, progress has been made in the application of the simultaneous transmission of identifying signals and traffic, on channels using F1 or single sideband reduced carrier emissions, particularly as regards extension of the

* This Report which replaces Report No. 91, was adopted by Correspondence (see page 9). The Bielorussian S.S.R., the Ukrainian S.S.R. and the U.S.S.R. reserved their opinions on this Report.

reduced carrier keying method to radiotelegraph and facsimile emissions (Docs. Nos. VIII/5 and 183 of Los Angeles, 1959).

1.1 As a result of the experience gained by some operating agencies, the method of keying in amplitude the reduced carrier of any single or independent sideband transmissions as recommended in § 3.2.1 of Recommendation No. 323 can be adopted. The details of the methods are described in Annex II of Doc. 56 of London, 1953 and Doc. 183 of Los Angeles, 1959.

2. Two methods have been used for identifying F1 emissions simultaneously with traffic:

2.1 One method, (Doc. 468 of Warsaw, 1956) is to superimpose an audio modulation which produces a phase modulation at the transmitter output. A low level amplitude modulation is applied to the exciter and this ultimately produces phase modulation through the limiting action of the following class C amplifier. The audio tone is keyed and applied across the common cathode resistor of the balanced modulator. This results in the production of additional sidebands on either side of the main carrier with a displacement depending on the frequency of the audio tone employed.

It has been found that satisfactory identification is obtained without interference to traffic if the amplitude of the sidebands is about 32 db below that of the carrier. Continuous repetition of the identifying signal at a rate of 8 wpm is used. The keying device consists of a notched "keying wheel" through which a beam of light is projected thereby operating a photo-electric cell. An ordinary communications receiver with the beat-frequency oscillator turned off is used for reception of the keyed identifying signal.

2.2 Another method has been developed which superimposes on the carrier an additional frequency modulation at small index and at 400 c/s, keyed by the identification signal. The conditions under which the method is used and the results obtained are described in Doc. 183 of Los Angeles, 1959).

3. Keyed amplitude modulation which is superimposed on frequency modulation for identifying signals has, for economic reasons, not been generally applied because the method used employed high-level modulation.

A method for identifying single-sideband multi-channel systems by the insertion of a keyed audio tone on one of the channels was found to be unsatisfactory due, particularly, to the difficulties encountered by monitoring observers.

4. For base stations used in the land mobile radiotelephone service, a system is in operation that automatically inserts an audio tone, keyed in International Morse Code, for the identification of the station before the transmitter is shut down (Doc. VIII/5 of Los Angeles, 1959). The tone is inserted into the speech amplifier of the base station and keyed by an electrically-driven code wheel.

Although this system does not meet the criteria of Question No. 187 (VIII), it was reported as of possible interest to other administrations and to indicate the apparent need for extending automatic identification methods throughout some radio services.

5. It has also been suggested that it would simplify the problems and ease the economic burden of operating companies if identification could be accomplished, when inserting or superimposing identifying signals simultaneously with traffic, by the use of a common means of identification on all transmitters at a particular transmitting centre. The common means of identification might link the name of the operating agency and the location of the transmitting centre. In addition a specific individual identifying signal might be employed to supplement the use of such a common identifying signal where necessary, when initiating or terminating operation on any particular transmitter.

REPORT No. 172 *

SPECTRUM MEASUREMENT BY MONITORING STATIONS

(Study Programme No. 103 (VIII))

(London, 1953 — Warsaw, 1956 — Los Angeles, 1959)

Study Programme No. 103 (VIII)—Spectrum Measurement at Monitoring Stations, was assigned to Study Group VIII at the VIIIth Plenary Assembly at Warsaw, 1956. Study Programme No. 103 (VIII) replaced Study Programme No. 70 of London, 1953.

The subject has been given consideration by several countries (Doc. 34, 38, 42, 572, of Warsaw, 1956 and Docs. VIII/10, VIII/13 and 184 of Los Angeles, 1959). It is therefore possible to enlarge upon the previous report on this subject (Report No. 68, of Warsaw, 1956).

1. Spectrum measurements made at a location remote from the transmitter suffer some limitations as compared to measurements at the transmitter because of noise, fading and interference. Noise imposes a restriction upon the dynamic range that can be accommodated in a given measurement. Although the noise level as related to the signal level imposes a definite limitation, certain valid measurements may be performed on those components of the signal which exceed the noise level. Except during periods of high atmospheric noise levels, or where large dynamic ranges are involved, noise is not likely to seriously limit the measurements which may be performed.

While errors of measurement can occur under adverse fading conditions, these can be reduced, and perhaps largely removed, either by making measurements when fading is absent or by averaging the results of a number of successive measurements. Similarly, a number of measurements is required to determine the variation of the spectrum and bandwidth with the variation of the modulation of the omission under normal traffic conditions.

2. It is considered that, in general, a spectrum analyser of the type described in § 1.1 of Recommendation No. 229, is the most suitable for use at monitoring stations. With this equipment the emission spectrum is analysed by passing each component successively through a narrow-band filter of fixed frequency, by heterodyning the signal with an external frequency, varied either automatically or manually. It is considered that the spectrum analyser should be capable of simple and rapid operation and that for monitoring work, this feature is more desirable than high accuracy. For use in the frequency range below about 30 Mc/s for narrow-band emissions, the swept-frequency range should be variable from about 1 kc/s to 100 kc/s.

2.1 A spectrum analyser for measurement of wide-band emissions employs an input centre frequency of 30 Mc/s. The scanning speed is continuously variable from 1 to 60 sweeps per second. Three amplitude scales are provided, namely: linear, 40 db logarithmic, and 10 db square law. This instrument is well suited for observation and analysis of various types of broadband emissions such as FM broadcast and television transmissions.

2.2 An energy spectrum recorder is described in Doc. VIII/13 of Los Angeles, 1959. This device makes a chart record of spectrum occupancy in terms of available power from a standard antenna.

* This Report which replaces Report No. 68, was adopted unanimously.

3. A somewhat different approach to the measurement of bandwidth is described as follows: Endeavours have been made to determine the bandwidth occupied by an emission by way of the signal shape instead of by analysing the spectrum. Such experiments have, for the time being, been made for Class A1 emissions only, starting from the fact that the bandwidth occupied is a function of the shortest build-up (and decay) time of the emitted signals (see Recommendation No. 230, § 2.1.3). Apparatus for the analysis of the spectrum in this manner, directly at the transmitter, has already been developed. Similar equipments, by which the analysis of the spectrum can be made at locations remote from the transmitter, are still under construction.

4. The effect of fading: The comparison between 60 single measurements of A1 emissions taken at the transmitter and in the far field (up to 425 km), resulted in a maximum deviation of 16%. The average value of the deviations amounted to 4.8%. The differences in the results of the measurements at the transmitter and those taken far away may be explained by the deformation due to the fading effects of the signals. In order to minimize the fading effects as far as possible, photographs were only taken when, according to the judgment of the operator, an undistorted signal appeared on the screen display. Moreover, the measurements were preferably taken mid-way between a fading minimum and a fading maximum. Measurements made under extreme fading conditions will not yield satisfactory results.

5. Effect of interference: The effect of interference was investigated by superimposing a received non-fading A1 signal with a simulated interference signal of variable frequency generated locally. It was found that the wanted signals could still be evaluated with a signal-to-interference ratio as low as 35 db. With signal-to-interference ratios lower than 35 db, evaluation was no longer possible, because the 10% value of the wanted signal could not then be recognized.

6. Spectrum analysers may also be valuable in the recognition and classification of emissions, particularly complex emissions. Many types of emissions have certain peculiar combinations of characteristics which, when viewed on a spectrum analyser by a trained observer, may provide valuable information leading to the recognition of the emission. For example, presence or absence of a carrier, presence of discrete sub-channels as in the case of frequency-division multiplex, relationship of the various repetitive components of the emission with each other both with respect to frequency and level, total occupied bandwidth, repetition rate of recurrent phenomena and numerous other characteristics of known emissions may be observed and catalogued. Photographs of spectrum analyser displays of known emissions may be kept available to the monitoring observer for reference and for comparison with questionable emissions.

7. Spectrum analysers have also been used to advantage in connection with frequency measurements in the presence of interference, where matching of the frequency of the measuring equipment against the unknown frequency by aural methods is difficult. By observing the two signals on the spectrum analyser, the frequency of the measuring equipment may be adjusted to that of the unknown carrier or to other discrete components in the signal. The same method may be used in determining the carrier frequency of a suppressed-carrier emission as long as some vestige of the carrier can be observed on the spectrum analyser screen.

8. Results that have been obtained show that very satisfactory measurements of the spectra and bandwidths of emissions on frequencies below 30 Mc/s can be obtained except under adverse conditions of fading, noise or interference. These measurements can be of considerable value in detecting emissions using excessive bandwidth which may cause interference. Less experience has been had in the measurement of spectra of emissions on frequencies above 30 Mc/s. However, the frequency range of equipment available for such measurements has been extended to approximately 200 Mc/s.

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SECTION K

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REPORT No. 37 *

DECIMAL CLASSIFICATION

(Question No. 72 (XIV))

(London, 1953)

1. Present state of the question as from the initial conditions.

1.1 It is the function of the International Federation for Documentation (F.I.D.) to ensure, when necessary, the revision of questions out of date or no longer adequate in respect of the Universal Decimal classification (U.D.C.).

1.2 With respect to the whole range of electrical technology the F.I.D. has entrusted this task to a committee consisting of specialists in this field, the International Committee for the Application of Decimal Classification in the Field of Electrical Technology (C.I.C.E.).

1.3 With respect to the subdivisions appropriate to telecommunication, the C.I.C.E. has set up a further group of specialists, the International Sub-Committee for the Classification of Telecommunications (S.C.I.C.T.), composed of telecommunication documentalists and technicians.

1.4 The F.I.D. has secured the following aid from the Specialised Secretariat of the C.C.I.R. in respect of the task allotted to the S.C.I.C.T.: jointly with the Directors of the C.C.I.T. and the C.C.I.F., and with the concurrence of the International Chairman of Study Group No. XIV, the Director of the C.C.I.R. has helped the F.I.D. to obtain from several administrations, members of the I.T.U., the nomination of competent personalities for this task; the three Directors of the C.C.I.s have jointly requested the F.I.D. to seek a united plan of classification within the entire field of telecommunications. They abstained from entering into any commitments vis-à-vis the F.I.D. in respect of the method of possible utilization of the U.D.C. for the needs of the C.C.I.s.

1.5 Duly noting this reservation, this initiative on the part of the Director of the C.C.I.R. has launched the study of Question No. 72 (XIV), due account being taken of its complexity and of the consequent desirability of avoiding undue haste; it has provided the most suitable means for drawing from the U.D.C. the maximum help to be expected from this system.

2. New conditions relating to the question.

2.1 The C.C.I.T. has recently informed the C.C.I.R. (London Doc. No. 406) of the stand taken on this subject by the last plenary session (Arnhem, June 1953, Recommendation I.5 modifying Recommendation No. 241). Due consideration having been given to the importance of the problem of classification and the fact that the solution adopted by the U.D.C. has been put into practice, the text adopted, nevertheless, reopens the question of the very principle of this solution, pointing out that: the resources which can be expected from it seem to be more suitable to the needs of librarians and to classification of general works, and that they are much less suitable for the needs of technicians; they become less useful as the subjects concerned become more precise and more detailed, noting also that the desired classification is not only to avoid unfortunate juxtapositions, but more especially to provide a maximum of facilities and usefulness when searching for documents with one or several given aspects.

The Recommendation which follows it expresses the view that the three C.C.I.s should take a common stand in respect of this question and declare their intention of following the work of the S.C.I.C.T. as observers and without commitments.

2.2 The French Administration has put forward (Doc. No. 354 of London) a proposition inspired with the same considerations as those set forth in the preceding paragraph. It draws

* This Report was adopted unanimously.

attention to the fact that the problem of classification allows of approaches towards other solutions than those which, as in the case of the U.D.C. and almost all systems so far proposed, recognise no other principle than that of a hierarchy or ramifications which distort the reality of the matter instead of being in keeping with it. It points out that some of the documentalists of the French Union of Documentary Organisations tend to move away from the U.D.C. in seeking a solution to the problem starting from a fundamentally different conception, and that an attempt at classification with a combinatory structure is under study at the (French) National Scientific Research Centre. It suggests to the C.C.I.R. that it might give its attention to these new approaches.

3. Conclusions.

The VIIIth Plenary Assembly of the C.C.I.R. considers that the line of action to be followed until the next Plenary Assembly should be as follows:

3.1 in its relations with the F.I.D. or its specialised groups, the C.C.I.R. should avoid any official participation in the work of the S.C.I.C.T.;

3.2 the Director of the C.C.I.R. should keep himself informed of the progress of this work and submit the results to Study Group No. XIV so that the latter may consider the possibility of applying it to the needs of the C.C.I.R., using in this study any comparable material which may be available to it;

3.3 a future Plenary Assembly will have to decide on its possible use by the C.C.I.R.

REPORT No. 95 *

DECIMAL CLASSIFICATION

Complement to Report No. 37

(Question No. 72 (XIV))

Warsaw, 1956)

A report on the progress of the work of the S.C.I.C.T. (International Sub-Committee for the application of the Decimal Classification to Telecommunication), set up by the F.I.D. (Fédération Internationale de Documentation), is given in Doc. No. 380 (Warsaw). This document has been studied during the VIIIth Plenary Assembly of the C.C.I.R., and the Chairman of S.C.I.C.T., Mr. Ferrari Toniolo, gave his comments; he explained that he had submitted the document himself and that it was not an official communication of the F.I.D. After the document had been studied, the following conclusions were reached:

1. From the existing data on the question it is not possible for the present Plenary Assembly to "decide on its possible use" (Report No. 37). The possibility of this decision is therefore referred to a later Plenary Assembly.

2. For the time being, the C.C.I.R. will confine itself to accepting the following proposal made by the Chairman of the S.C.I.C.T., designed to show the possible application of the U.D.C. in the sphere of the C.C.I.R. The S.C.I.C.T., without the assistance of the C.C.I.R., will prepare a list, classified according to the present revised edition of the U.D.C., for the various official documents of the C.C.I.R. (Recommendations, Reports, etc.) which will be in force after the VIIIth Plenary Assembly, and for the whole set of working documents dealt with during the present Plenary Assembly.

* This Report was adopted unanimously.

REPORT No. 173 *

POSSIBLE AMENDMENTS TO THE DEFINITIONS
IN THE RADIO REGULATIONS, ART. 1

(G. R. chap. 18)
(Study Group No. XIV)

(Los Angeles, 1959)

Among the terms and definitions contained in C.C.I.R. Recommendations, the ones which would appear to be sufficiently important to warrant modification of the list of definitions in Article 1 of the Radio Regulations are given below in the two languages at present used for its work by Study Group XIV, i.e. French (left column) and English (right column).

In the margin on the left are shown first, *in italics*, the number allotted by the Radio Regulations to the corresponding definitions in the case of a proposed *modification* (e.g. 58), or in cases where an *additional insertion* is to be made in the appropriate place a number followed by a letter (e.g. 58 a); then, below *in brackets* the indication of the Recommendation(s) of the C.C.I.R. giving rise to the proposal (e.g. Doc. 253). *Double brackets* are used to indicate that the Recommendation in question merely provided the basis, and not the actual text, for the purposed definition.

57	<i>Fréquence assignée à une station :</i> (transf. en 58 d, après 58 c).	<i>Frequency assigned to a station :</i> (transf. to 58 d, after 58 c).
57 a (Rec. No. 230)	<i>Temps d'établissement d'un signal télégraphique :</i> Temps pendant lequel le courant télégraphique passe du dixième aux neuf dixièmes (ou vice-versa) de la valeur qu'il atteint en régime établi.	<i>Build-up time of a telegraph signal :</i> The time during which the telegraphic current passes from one-tenth to nine tenths (or vice versa) of the value reached at the steady state.
58 (Recs. Nos. 230 and 231)	<i>Largeur de bande occupée par une émission :</i> Largeur de la bande de fréquences telle que, au-dessous de sa fréquence limite inférieure et au-dessus de sa fréquence limite supérieure, soient rayonnées des puissances moyennes égales chacune à un demi pour cent de la puissance moyenne totale rayonnée par l'émission considérée.	<i>Bandwidth occupied by an emission :</i> The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to one half per cent of the total mean power radiated by the emission.
58 a (Rec. No. 230)	<i>Largeur de bande nécessaire :</i> Pour une classe d'émission donnée, valeur minimale de la largeur de la bande de fréquence telle que, au-dessous de sa fréquence limite inférieure	<i>Necessary bandwidth :</i> For a given class of emission, the minimum value of the frequency bandwidth such that, below its lower and above its upper frequency

* This Report was adopted by correspondence (see page 9). The United States of America and the United Kingdom reserved their opinion on this Report.

rieure et au-dessus de sa fréquence limite supérieure, soient rayonnées des puissances moyennes égales chacune à un demi pour cent de la puissance totale rayonnée, cette valeur minimale suffisant à assurer la transmission de l'information à la vitesse voulue et avec la qualité requise, dans des conditions techniques données.

58 b
(Rec. No. 231)

Bande de fréquences occupée par une émission :

Bande de fréquences du spectre hertzien telle que, au-dessous de sa fréquence limite inférieure et au-dessus de sa fréquence limite supérieure, soient rayonnées des puissances moyennes égales chacune à un demi pour cent de la puissance moyenne totale rayonnée par l'émission considérée.

58 c
(Rec. No. 233)

Bande de fréquences assignée à une station :

Bande de fréquences dont le centre coïncide avec la fréquence assignée à la station et dont la largeur est égale à la largeur de bande nécessaire augmentée du double de la valeur absolue de la tolérance de fréquences.

58 d
(Rec. No. 233)

Fréquence assignée :

Centre de la bande de fréquence assignée à une station.

58 e
(Rec. No. 233)

Fréquence caractéristique d'une émission :

Fréquence aisément identifiable et mesurable dans une émission donnée.

58 f (cf 59.1)
(Rec. No. 233)

Fréquence de référence :

Fréquence ayant une position fixe et bien déterminée par rapport à la fréquence assignée. Le décalage de cette fréquence par rapport à la fréquence assignée est, en grandeur et en signe, le même que celui de la fréquence caractéristique par rapport au centre de la bande de fréquence occupée par l'émission.

Note 1. — La notion de fréquence de référence est rendue nécessaire du fait que la fréquence centrale de certaines classes d'émissions n'est pas facile à identifier et à mesurer.

limits the mean powers radiated, are each equal to one half per cent of the total mean radiated power, this minimum value being sufficient to ensure the transmission of information at the rate and with the quality required for the system employed, under specified conditions.

Frequency band occupied by an emission :

The frequency band in the radio frequency spectrum such that, below its lower and above its upper frequency limits, the mean power radiated are each equal to one half percent of the total mean power radiated by the emission.

Frequency band assigned to a station :

The frequency band, the centre of which coincides with the frequency assigned to the station, and the width of which equals the necessary bandwidth, plus twice the absolute value of the frequency tolerance.

Assigned frequency :

The centre of the frequency band assigned to a station.

Characteristic frequency of an emission :

A frequency which can be easily identified and measured in a given emission.

Reference frequency :

A frequency having a fixed and specified position with respect to the assigned frequency. The displacement of this frequency with respect to the assigned frequency has the same absolute value and sign as that of the displacement of the characteristic frequency with respect to the centre of the frequency band occupied by the emission.

Note 1. — The idea of a reference frequency is made necessary by the fact that the centre frequency of certain classes of emission is not easily identified and measured.

Note 2. — Pour certaines classes d'émissions, il est nécessaire de spécifier la valeur d'une ou plusieurs fréquences de référence, en même temps que la fréquence assignée. Par exemple, dans le cas des stations de télévision, les fréquences caractéristiques sont celles des porteuses d'image et de son, et les valeurs des fréquences de référence correspondantes devraient être spécifiées.

Note 2. — For certain classes of emissions it is necessary to specify the value of one or more reference frequencies as well as the assigned frequency. For example, in the case of television broadcast stations, the characteristic frequencies are those of the vision and sound carriers, and the figures for the corresponding reference frequencies should be specified.

59

Tolérance de fréquence :

(Rec. No. 233)

Ecart maximum admissible entre la fréquence assignée à une station et la fréquence située au centre de la bande de fréquences occupée par l'émission correspondante *ou* entre la fréquence de référence et la fréquence caractéristique. La tolérance de fréquence est exprimée en c/s, ou en valeur relative par rapport à la fréquence assignée.

Frequency tolerance :

The maximum permissible deviation, with respect to the frequency assigned to a station, of the centre frequency of the frequency band occupied by the corresponding emission, *or*, with respect to the reference frequency, of the characteristic frequency of the emission. The frequency tolerance is expressed in c/s or as a fractional value of the assigned frequency.

59.1

(Note sur « la notion de fréquence de référence »; à supprimer: cf. 58 f).

" (Note on " the concept of a reference frequency "; to be deleted: cf. 58 f).

64 a'

Rayonnement hors bande :

(Rec. No. 230)

Puissance rayonnée par l'émission en dehors de la bande nécessaire. Le rayonnement hors bande ne comprend pas les rayonnements sur des fréquences éloignées, tels que les rayonnements non essentiels.

Out-of-band radiation of an emission :

The power radiated by an emission outside the necessary bandwidth. The out-of-band radiation does not include radiations on remote frequencies such as spurious emissions.

64 a

Rayonnement non essentiel :

(Rec. No. 232)

Rayonnement sur une (ou des) fréquence(s) située(s) hors de la bande nécessaire et dont le niveau peut être réduit sans affecter la transmission de l'information correspondante. Les rayonnements harmoniques, les rayonnements parasites et les produits d'intermodulation sont compris dans les rayonnements non essentiels, mais les rayonnements au voisinage immédiat des limites de la bande nécessaire et qui sont le résultat du processus de modulation utile pour la transmission de l'information en sont exclus.

Spurious emission :

Emission on a frequency or frequencies which are outside the necessary band, and the level of which may be reduced without affecting the corresponding transmission or information. Spurious emissions include harmonic emissions, parasitic emissions and intermodulation products, but exclude emissions in the immediate vicinity of the necessary band, which are a result of the modulation process for the transmission of information.

64 b

Rayonnement harmonique :

(Rec. No. 232)

Rayonnement non essentiel sur des fréquences qui sont des multiples entiers de celles comprises dans la bande occupée.

Harmonic emission :

Spurious emission on frequencies which are whole multiples of those comprised in the band occupied.

65
(Rec.No.168))

Gain relatif d'une antenne, dans une direction donnée (1) :

Rapport, exprimé en décibels, des champs produits dans la direction considérée (1), en un point suffisamment éloigné pour que le champ y soit inversement proportionnel à la distance, par les rayonnements respectifs, pour une même puissance d'alimentation (2), de l'antenne qu'il s'agit de caractériser et d'un doublet en demi-onde, considéré dans son plan médian, isolé dans l'espace et sans pertes.

Motifs : Ce rapport étant exprimé en décibels, c'était inutilement compliquer la définition que d'y introduire les champs par leurs carrés. La nouvelle définition proposée, vise en outre à plus de clarté et peut se simplifier beaucoup (cf. texte 65.2 et motifs correspondants).

65.1
(Rec.No.168))

[Note (1) au point 65]: En l'absence de la mention d'une direction spécifiée, il s'agit alors implicitement de la direction pour laquelle la grandeur prend sa valeur maximale.

Motifs : Unification de rédaction pour 65.1 et 66.1.

65.2
(Rec.No.168))

[Note (2) du point 65]: Cette définition peut être notablement allégée. Tout le début, jusqu'aux mots « ... même puissance d'alimentation (2), ... », peut être remplacé par « Rapport, exprimé en décibels, pour la direction considérée (1), des *forces cymomotrices spécifiques nettes*... », la notion ainsi introduite étant elle-même définie de la manière suivante:

Force cymomotrice d'une antenne, dans une direction donnée (cf. note 65.1): Produit exprimé en volts, du champ électrique de l'antenne en un point donné dans la direction considérée (cf. note 65.1), par la distance de l'antenne à ce point, celui-ci devant être assez éloigné pour que ce produit reste constant dans cette direction. La force cymomotrice est dite *spécifique nette* lorsque la puissance fournie à l'antenne a une valeur (de crête, ou moyenne, selon précisions à donner conformément aux définitions 61 à

Relative gain of an antenna in a given direction (1) :

The ratio, expressed in decibels, of the field strengths produced in the direction under consideration (1), at a point sufficiently distant for the field strength to be inversely proportional to the distance, by the respective radiations for the same input power (2) from the antenna under consideration and from a half-wave doublet, loss free, isolated in space and considered in its median plane.

Reasons for the change : This ratio being expressed in decibels, it would complicate the definition needlessly if the squares of the field strengths were to be used. The new definition proposed tends to a greater clarity and may be considerably simplified (cf. § 65.2 and the corresponding reasons).

[Note (1) to § 65]: In the absence of a specified direction being mentioned, it implies that the direction in which the field strength has its greatest value is taken.

Reasons : Unification of § 65.1 and 66.1.

[Note (2) to § 65]: This definition may be shortened considerably. All the beginning, up to the words " ... same input power (2) ... " may be replaced by " Ratio in decibels for the direction under consideration (1), of the *specific nett cymomotive forces*... ", the idea introduced here is itself defined in the following manner:

Cymomotive force of an antenna in a given direction (see note to § 65.1): The product expressed in volts of the electric field of the antenna at a given point in the direction under consideration (see note to § 65.1), and the distance of the antenna from this point, the antenna being sufficiently distant for the above product to remain constant in the direction given. This is defined as the *specific nett cymomotive force* if the power fed to the antenna has a value (peak, or mean according to the values to

64) de un kilowatt; elle est dite *spécifique brute* lorsque c'est la puissance rayonnée par l'antenne qui a cette valeur.

Motifs : L'Avis n° 168 du C.C.I.R., comme l'Avis n° 108 qu'il remplace, introduit cette notion de force cymomotrice spécifique (avec d'assez longs développements et d'une façon quelque peu différente) précisément comme base d'étude des diagrammes d'antennes, ce qui implique d'en tenir compte dans la définition des gains d'antennes, les diagrammes étant des représentations des gains.

Cette définition n'est toutefois proposée que sous forme de note pour tenir compte, conformément au procès-verbal de la dernière séance de la Commission d'études XIV du C.C.I.R. lors de la dernière Assemblée plénière, de ce qu'il n'y a pas unanimité au sujet de l'intérêt de cette notion.

be specified in accordance with definitions 61 to 64) of one kilowatt; it is called *specific gross* if the power radiated from the antenna has this value.

Reasons : Recommendation No. 168 of the C.C.I.R. as well as Recommendation No. 108 which it replaces, introduces the conception of specific cymomotive force (with a fairly long development and in a slightly different manner) exactly as a basis for study of antenna radiation diagrams, which implies that if count is taken of this in the definitions of antenna gain, the diagrams will represent antenna gains.

This definition is however proposed only in form of a note in order to take into account, in accordance with the minutes of the final session of Study Group XIV of the C.C.I.R. during the last Plenary Assembly, that there was a lack of unanimity on the subject of the importance of this conception.

66
(Rec.No.168))

Gain isotrope (ou gain absolu, ou coefficient de directivité) d'une antenne, dans une direction donnée ⁽¹⁾ :

Même définition que ci-dessus en 65, en y remplaçant la fin, à partir des mots « ... d'un doublet... » par « d'une antenne isotrope, isolée dans l'espace et sans pertes ».

Isotropic gain (absolute gain, or coefficient of directivity) of an antenna in a given direction (1) :

The same definition as that of § 65 above with the replacement of the phrase beginning with the words " ... from a half-wave doublet..." by "from an isotropic antenna, loss free and isolated in space".

Motifs : Les mêmes que pour le point 65.

Reasons : The same as for § 65.

66.1
(Rec.No.168))

[Note identique à la note 65.1 ci-dessus].

[Note identical with that of § 65.1 above].

Motifs : Les mêmes que pour le point 65.1.

Reasons : The same as for § 65.1.

66.2
(Rec.No.168))

[Note identique à la note 65.2 ci-dessus].

[Note identical with that of § 65.2 above].

Motifs : Les mêmes que pour le point 65.2.

Reasons : The same as for § 65.2.

67 and 68
(Rec.No.168))

[Texte commun] *Diagramme de directivité d'une antenne* :

Représentation graphique, en coordonnées polaires ou cartésiennes du champ, de la force cymomotrice ou — sous forme logarithmique — du gain d'une antenne dans les différentes directions d'un plan ou d'un cône spécifiés, ou d'une famille de

[Common text] *Directivity diagram of an antenna* :

A graphical representation, in polar or cartesian coordinates, of the field, of the cymomotive force, or — in logarithmic form — of the gain of an antenna in different directions in a given plane or a given cone, or of a family of such surfaces.

telles surfaces. Cette représentation est en général simplement relative, l'unité graphique correspondant à la valeur maximale (représentée avec la cote 1) de la quantité à représenter.

Motifs : Ils découlent de ceux qui sont donnés pour 65.2 ou 66.2.

73 a * *Système de relais radioélectriques :*

Système de radiocommunication travaillant généralement sur des fréquences très élevées, constitué par plusieurs sections reliées par des relais.

73 b * *Faisceau hertzien :*

Système de radiocommunication travaillant sur des fréquences très élevées, en général des relais reliés par des faisceaux électromagnétiques de faible ouverture.

731. a.1 * *Note.* — En fait, il est si général que les caractéristiques définies en 73 a et 73 b soient réunies qu'on se dispense, en pratique, de le préciser et que l'usage d'un seul terme est suffisant : faisceaux hertziens.

This representation is generally purely relative, the unit of scale being taken as the maximum value (represented by the value 1) of the quantity represented.

Reasons : They derive from those which were given for § 65.2 or 66.2.

Radio relay system :

Radiocommunication system usually operating at very high frequencies and consisting of a number of sections linked by relays.

(No corresponding term in English).

Note. — In fact, the characteristics defined in § 73 a and 73 b are so often found together that there is no distinction in practice and that the use of one term is enough.

ANNEXE

Note by the Director of the C.C.I.R.

The proposition appearing below did not arrive in time for it to be approved, together with Doc. No. 774 (which has become Report No. 173), according to the special procedure indicated on page 9. Although it cannot therefore be considered as forming a part of Report No. 173, this proposition is appended for information purposes.

CORRIGENDUM TO DOC. NO. 774 OF LOS ANGELES, 1959

A proposition has been omitted in the list of "possible modifications to the definitions in the Radio Regulations, Art. 1" which was the subject of Report No. 173 established by Study Group XIV at its last meeting (see Doc. 770 of Los Angeles, 1959, § 3, last paragraph). The following additional matter should, therefore, be inserted in the bilingual list.

Def. 4. *Radiocommunication* : Télécommunication réalisée à l'aide d'ondes hertziennes librement propagées.

Motifs : Cette proposition de modification ne se trouve pas dans tel ou tel Avis du C.C.I.R., mais c'est avec la signification ainsi précisée que doivent être compris tous les travaux du C.C.I.R.

Def. 4. *Radiocommunication* : Telecommunication carried out by means of *freely-propagated Hertzian waves*.

Reasons : This proposition for a modification is not to be found in any particular Recommendation of the C.C.I.R., but all the work of the C.C.I.R. should be considered as having the signification given above.

* For these three points, the proposition presented here does not particularly rely on a Recommendation of the C.C.I.R. it is derived from the majority of those Recommendations of the C.C.I.R. issued from Study Group IX (now they all use the terminology defined here above).

