INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

XIIth PLENARY ASSEMBLY

NEW DELHI, 1970

VOLUME V

PART 1

BROADCASTING SERVICE (SOUND)
(STUDY GROUP 10)

PROBLEMS COMMON TO SOUND BROADCASTING AND TELEVISION
(SUBJECTS COMMON TO STUDY GROUPS 10 AND 11)

Published by the

INTERNATIONAL TELECOMMUNICATION UNION

GENEVA, 1970

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BROADCASTING SERVICE (SOUND)

RECOMMENDATIONS AND REPORTS

10A Amplitude-modulation sound broadcasting in bands 5 (LF), 6 (MF) and 7 (HF)

10B Frequency-modulation sound broadcasting in bands 8 (VHF) and 9 (UHF)

10C Sound broadcasting in the Tropical Zone

QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS

(Study Group 10)

PROBLEMS COMMON TO SOUND BROADCASTING AND TELEVISION

RECOMMENDATIONS AND REPORTS

10/11A Recording of sound and video programmes

10/11B Broadcasting service (sound and television) using satellites

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DISTRIBUTION OF TEXTS OF THE XIIth PLENARY ASSEMBLY OF THE C.C.I.R. IN VOLUMES I TO VII

Volumes I to VII, XIIth Plenary Assembly, contain all the valid texts of the C.C.I.R.

1. Recommendations, Reports, Resolutions, Opinions

1.1 *Numbering of these texts*

Recommendations, Reports, Resolutions and Opinions are numbered according to the system in force since the Xth Plenary Assembly.

When one of these texts is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. For example: Recommendation 253 indicates the original text is still current; Recommendation 253-1 indicates that the current text has been once modified from the original, Recommendation 253-2 indicates that there have been two successive modifications of the original text, and so on.

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

1.2 *Recommendations*

Number	Volume	Number	Volume	Number	Volume
45	VI	265, 266	V	374-376	III
48, 49	V	268	IV	377-379	I
77	VI	270	IV	380-393	IV
80	V	275, 276	IV	395-406	IV
100	I	279	IV	407-421	V
106	III	283	IV	422, 423	VI
139, 140	V	289, 290	IV	427-429	VI
162	III	302	IV	430, 431	III
166	I	304-306	IV	432, 433	I
182	I	310, 311	II	434, 435	II
205	V	313	II	436	III
214-216	V	314	IV	439-441	VI
218, 219	VI	325-334	I	442, 443	I
224	VI	335-340	III	444-446	IV
237	I	341	I	447-451	V
239	I	342-349	III	452, 453	II
240	III	352-359	IV	454-461	III
246	III	361	VI	462-466	IV
257, 258	VI	362-367	IV	467-474	V
262	V	368-373	II	475-478	VI

1.3 *Reports*

Number	Volume	Number	Volume	Number	Volume
19	III	226	IV	341-344	II
32	V	227-231	II	345-357	III
42	III	233-236	II	358, 359	VI
79	V	238, 239	II	361	VI
93	VI	241	II	362-364	III
106, 107	III	244-251	II	366	III
109	III	252	(1)	367-373	I
111	III	253-256	II	374-393	IV
112	I	258-266	II	394	VI
122	V	267	III	395-397	IV
130-137	IV	269-271	III	398-401	V
176-194	I	272, 273	I	403-407	V
195	III	275-282	I	409-412	V
196	I	283-290	IV	413-415	(1)
197, 198	III	292-294	V	416-423	I
200, 201	III	297-308	V	424-432	II
202	I	311-316	V	433-439	III
203	III	318-320	VI	440	(1)
204-214	IV	321	III	441	III
215	V	322	(1)	442-456	IV
216	VI	324-334	I	457-498	V
218, 219	IV	335	III	499-515	VI
222-224	IV	336-339	II	516	V
		340	(1)		

(1) Published separately.

1.4 *Resolutions*

Number	Volume	Number	Volume	Number	Volume
2-4	II	21-23	III	39, 40	VII
7, 8	II	24	VII	41-44	I
10	II	26, 27	VII	45-51	II
12, 13	II	30	II	52-54	III
14	III	33	VII	55, 56	IV
15, 16	I	36, 37	VII	57, 58	V
20	VI	38	V, VII		

1.5 *Opinions*

Number	Volume	Number	Volume	Number	Volume
2	I	22, 23	II	32–35	I
11	I	24	VI	36, 37	III
13, 14	IV	26-28	III	38-41	V
15, 16	V	29, 30	I	42, 43	VI

2. Questions and Study Programmes

2.1 *Text numbering*

2.1.1 *Questions*

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

— Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;

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

2.1.2 *Study Programmes*

Study Programmes are numbered to indicate the Question from which they are derived if any, the number being completed by a capital letter which is used to distinguish several Study Programmes which derive from the same Question. For example:

— Study Programme 1A/10, which would indicate that the current text is the original version of the text of the first Study Programme deriving from Question 1/10;

— Study Programme 1C/10, which would indicate that the current text is the original version of the text of the third Study Programme deriving from Question 1/10;

— Study Programme 1A-1/10 would indicate that the current text has been once modified from the original, and that it is the first Study Programme of those deriving from Question 1/10;

— Study Programme 3-1A/10 would indicate that the current text is the original and that this Study Programme is the first deriving from Question 3-1/10, which has itself been once modified from the original;

— Study Programme 3-1B-1/10 would indicate that the current text has been once modified from the original, and that this Study Programme is the second of the group deriving from Question 3-1/10, which has itself been once modified from the original.

It should be noted that a Study Programme may be adopted without it having been derived from a Question; in such a case it is simply given a sequential number analogous to those of other Study Programmes of the Study Group, except that on reference to the list of relevant Questions it will be found that no Question exists corresponding to that number.

Also, the up-to-date number of the Question concerned is used in assembling the number of a Study Programme: this is to facilitate reference to the Volumes, but does not exclude the possibility of the Study Programme having been evolved before the latest version of the Question.

2.2 *Arrangement of Questions and Study Programmes*

The plan shown on page 8 indicates the Volume in which the texts of each Study Group are to be found, and so reference to this information will enable the text of any desired Question or Study Programme to be located.

PLAN OF VOLUMES I TO VII
XIIth PLENARY ASSEMBLY OF THE C.C.I.R.

(New Delhi, 1970)

VOLUME I	Spectrum utilization and monitoring (Study Group 1).
VOLUME II (Part 1)	Propagation in non-ionized media (Study Group 5).
VOLUME II (Part 2)	Ionospheric propagation (Study Group 6).
VOLUME III	Fixed service at frequencies below about 30 MHz (Study Group 3). Standard frequencies and time signals (Study Group 7). Vocabulary (CIV).
VOLUME IV (Part 1)	Fixed service using radio-relay systems (Study Group 9). Coordination and frequency sharing between communication-satellite systems and terrestrial radio-relay systems (subjects common to Study Groups 4 and 9).
VOLUME IV (Part 2)	Fixed service using communication satellites (Study Group 4). Space research and radioastronomy (Study Group 2).
VOLUME V (Part 1)	Broadcasting service (sound) (Study Group 10). Problems common to sound broadcasting and television (subjects common to Study Groups 10 and 11).
VOLUME V (Part 2)	Broadcasting service (television) (Study Group 11). Transmission of sound broadcasting and television signals over long distances (CMTT).
VOLUME VI	Mobile services (Study Group 8).
VOLUME VII	Information concerning the XIIth Plenary Assembly. Structure of the C.C.I.R. Complete list of C.C.I.R. texts.

Note. — To facilitate reference, page numbering is identical in all three versions of each Volume, that is, in English, French and Spanish.

VOLUME V

PART 1

INDEX *

BROADCASTING SERVICE (SOUND)
(Study Group 10)

PROBLEMS COMMON TO SOUND BROADCASTING AND TELEVISION
(Subjects common to Study Groups 10 and 11)

Study Group 10

* In this Volume, Recommendations and Reports dealing with the same subject are collected together. These texts are numbered in such a manner that they cannot be presented in numerical order and at the same time, in numerical sequence of pages. Consequently, this index, in numerical order of texts, does not follow the numerical sequence of pages.

REPORTS

QUESTIONS AND STUDY PROGRAMMES

RESOLUTIONS

OPINIONS

Subjects of common interest to Study Groups 10 and 11

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BROADCASTING SERVICE (SOUND)

STUDY GROUP 10

Terms of reference

To study:

1. technical aspects of the broadcasting service (sound), including the use of satellites;
2. the special problems of broadcasting in the Tropical Zone, taking into account the standards required for good quality service; interference in the shared bands; power required for an acceptable service; design of suitable transmitting antennae; receiving equipment; optimum conditions for utilization of the frequency bands and other associated questions;
3. standards for audio-frequency recording to facilitate the international exchange of programmes.

Chairman: A. Prose WALKER (United States of America)

Vice-Chairman: S.S. AIYAR (India)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 10

Organization of the Study Group

At the XIIth Plenary Assembly, decisions taken require a realignment of the organizational structure of Study Group 10. Former Study Group XII was discontinued and its work incorporated into Study Group 10. Videotape and film recording and reproducing for the international exchange of television programmes, were transferred to Study Group 11. However, certain aspects of recording relating to both sound and vision were considered appropriate for joint study until such time as a clearer delineation of the subjects can be made. The service aspects of satellite broadcasting were included in the terms of reference, as will be noted above. By virtue of the commonality of many parameters involved in both sound and vision, it appears desirable that these matters also be jointly studied with Study Group 11. During discussion in Plenary of Doc. X/1024, it was concluded that the existing terms of reference of both Study Groups 10 and 11 are sufficiently inclusive to encompass the technical aspects of sound and television transmissions intended for educational purposes.

In accordance with the above, it is recommended that the structure of the Sub-Groups be as follows:

- 10A: Amplitude-modulation sound broadcasting in bands 5 (LF), 6 (MF) and 7 (HF).
- 10B: Frequency-modulation sound broadcasting in bands 8 (VHF) and 9 (UHF).
- 10C: Sound broadcasting in the Tropical Zone.
- 10/11A: Recording of sound and vision programmes.
- 10/11B: Broadcasting service (sound and television) using satellites.

Highlights of the work to be accomplished

In consideration of the possibility of a Region 1 broadcasting planning conference some time in the future, the work of Sub-Group 10A assumes particular significance. The systems approach to the study of broadcasting problems, adopted in Question 25/10 and associated Study Programmes, has already shown promising results. Intensive effort should be devoted by Administrations to solve in a practical manner the particulars of this overall subject, to the end that more efficient use can be made of that part of radio-frequency spectrum allocated to broadcasting.

In the area of frequency-modulation broadcasting, new work is contemplated by several Administrations on a four-channel frequency-modulation stereophonic system. Although our work relating to the pilot-tone and polar systems has not yet been completed, this additional aspect lends interest. Significant work is in progress on providing more information and techniques for two or more additional sound programmes in both frequency-modulation sound broadcasting and television. It is hoped that more information will be provided during this period on polarization of emissions for improving reception in areas where multipath and shadowing take place.

The new terms of reference of the Study Group 10 appear to lay great emphasis on the problems of sound broadcasting in the Tropical Zone. The work in progress on field strengths produced by transmitters, the design of antennae for tropical emission and reception, assessment of fading allowances and determination of noise levels should be continued. Answers on the advantages of using frequency-modulation emissions in band 8 in the Tropical Zone are important to the future of such broadcasting. It should be recognized that only Administrations engaged in broadcasting in the Tropical Zone are in a position to supply information on all these subjects. The assistance of Study Group 6 and Sub-Group 10A should be helpful in resolving some of these problems.

Considerable work has been done on measurement and control of the subjective loudness of broadcasting programmes. The establishment of an Interim Working Party should further the rapid resolution of the matter. Many Administrations are anxiously awaiting the most practicable solution to this complicated subject.

The adoption of Recommendations on film and videotape for the international exchange of programmes, closes this area of work for Study Group 10. It should be possible to provide additional information on audio-tape speeds suitable for use as secondary standards. Considerable work is being done on improvement of the characteristics of recordings on cassettes. A successful videotape cartridge machine has been produced. It would seem that advancements in these areas would be promising during this period (see Report 467). Many Administrations are keenly interested in automatic programming systems. Although there are no current Questions/Study Programmes on this subject, this would seem to be an appropriate area for study.

A special preparatory meeting of appropriate Study Groups to prepare recommendations for the World Administrative Radio Conference for Space Telecommunications will be held early in 1971. All the work relative to satellite broadcasting should be so expedited that it will be ready for that meeting. Reference to the particular work programmes will indicate the subjects to be emphasized. Resolution 38 establishes an Interim Working Party to study broadcasting-satellite systems, taking the technical aspects and relative capital and running costs into account. This work was based on Study Programmes 20-1B/10 and

5-1C/11. This Interim Working Party will not report to Study Groups 10 and 11, but to the Director, C.C.I.R. Their work is to be available for the special C.C.I.R. Preparatory Meeting for the World Administrative Radio Conference for Space Telecommunications.

As in the past, the new or developing countries are urged to take a more active part in the work of Study Group 10. It is only by knowing of their special problems that the work of the Study Group can be more responsive to their needs.

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SECTION 10A: AMPLITUDE-MODULATION SOUND BROADCASTING IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 80

BROADCASTING IN BAND 7 (HF)

Directional antennae

(Question 14/10)

The C.C.I.R., (1951)

CONSIDERING

(a) that the formation of strong subsidiary lobes of radiation can be avoided by the multiple feeding of, and appropriate current distribution in, appropriately spaced radiation elements;

(b) that, by this means, it is theoretically possible to reduce the subsidiary lobes to a small value for a limited angle of slew of the main beam, provided the working frequency does not differ materially from the frequency for which an array is designed;

(c) that the realization of these conditions is, however, not considered to be practicable on grounds of complexity of installation, difficulty of operation and maintenance of design performance;

RECOMMENDS

that in practical operating conditions, for purposes of calculating interference, the field strength in directions other than that of the main lobe cannot be assumed to be less than 222 mV/m at a distance of one kilometre for 1 kW of power supplied to the antenna *.

RECOMMENDATION 205-1

BROADCASTING IN BAND 7 (HF)

Use of synchronized transmitters

The C.C.I.R. (1953 – 1956 – 1966)

UNANIMOUSLY RECOMMENDS

that synchronized transmitters at the same site, driven by a common oscillator and modulated by the same programme in the correct phase, may be considered not to introduce any appreciable deterioration in reception:

* Refer to statement by the C.C.I.R. Secretariat on the subject *The gain, directivity and protection ratio of a directional antenna or antenna array*, Doc. 24 of Washington as reproduced in Geneva, 1951.

1. for non-overlapping service areas;

2. for overlapping service areas, provided that due consideration is given to:
   — the shape and size of the reception area;
   — the availability of suitable antennae with similar transmission characteristics;
   — the propagation conditions over the transmission paths, corresponding to the antennae.

These considerations become more critical as the transmission distance increases.

RECOMMENDATION 262-1

BROADCASTING IN BAND 7 (HF)

Effects of closer spacing between carriers

The C.C.I.R. (1959 - 1966)

UNANIMOUSLY RECOMMENDS

that at least with the majority of receivers in use, the radio-frequency wanted-to-interfering signal ratio to give satisfactory reception (see Note), when two transmitters use carrier frequencies 5 kHz apart, should not be considered to be less than when the transmitters use the same frequency (within 50 Hz).

Note. — Satisfactory reception is defined here as a condition when the interference from the unwanted signal can be deemed tolerable.

RECOMMENDATION 410

BROADCASTING IN BAND 7 (HF)

Use of more than one frequency per programme

The C.C.I.R., (1963)

CONSIDERING

that Article 10, No. 643, of the Radio Regulations, states: "... their number (of frequencies) should be the minimum necessary to provide satisfactory reception of the particular programme in each of the areas for which it is intended ...";

UNANIMOUSLY RECOMMENDS

1. that, wherever possible, only one frequency should be used to radiate a particular programme to a given reception area;

2. that in certain special circumstances, namely:
   — over certain paths, e.g. very long paths, those passing through the auroral zone, or paths over which the FOT is changing rapidly;
   — areas where the depth of the area extending outwards from the transmitter is too great to be served by a single frequency;

— when highly directional antennae are used to maintain satisfactory signal-to-noise ratios, thereby limiting the geographical area covered by such antennae;

it may be found necessary to use more than one frequency per programme;

3. that the decision to use more than one frequency per programme should be made on the merits of the particular case concerned.

RECOMMENDATION 411-1

BROADCASTING IN BAND 7 (HF)

Conditions for satisfactory reception

The C.C.I.R., (1963 - 1966)

CONSIDERING

that the International High Frequency Broadcasting Conference, Mexico City, 1948, requested the C.C.I.R. to study certain questions relating to the conditions for satisfactory reception in high-frequency broadcasting;

UNANIMOUSLY RECOMMENDS

that the values given in the Table below should be used for the fading factors necessary to ensure a satisfactory signal-to-interference ratio for given percentages of the time.

Ratio (dB)	*1*	*2*	*3*	*4*
Radio-frequency signal-to-interference	10	13	23	16
Wanted signal-to-atmospheric noise	6	16	22	17
Wanted signal-to-industrial noise	6	10	16	12

Column 1: the short-term fading allowance which must be made to ensure that the steady-state ratio is attained 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*, and is the overall variability allowance which must be made to ensure that the steady-state ratio is attained for 90% of any one 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 (in dB) given in columns *1* and *2*, and is the overall variability allowance which must be made to ensure that the steady-state ratio is attained for 90% of the time.

Note. — The figures in the above Table, relating to the time availability of service, were selected on a theoretical basis and on experience derived principally from broadcasting in band 6 (MF).

RECOMMENDATION 413-2

PRESENTATION OF THE RESULTS OF MEASUREMENTS OF RADIO-FREQUENCY PROTECTION RATIOS FOR SOUND BROADCASTING IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

(Question 25/10)

The C.C.I.R., (1963 – 1966 – 1970)

CONSIDERING

(a) that the value of protection ratio depends on a large number of parameters;

(b) that, if valid comparisons are to be made between values of protection ratios established by different workers, it is essential that as many as possible of these parameters be standardized;

UNANIMOUSLY RECOMMENDS

1. that, whenever possible, the results of measurements of the radio-frequency protection ratio between two broadcast signals should be presented in terms of the following characteristics and parameters:

- — type of modulation,
- — separation, Δf, between the carrier-frequencies (kHz) (Δf should lie between 0 and at least 10 kHz),
- — modulation index, k, of both signals,
- — occupied bandwidth, b,
- — type of the programmes of the wanted and unwanted signals,
- — characteristics of fading if present,
- — radio-frequency input voltage of the wanted signal, RF,
- — passband of the receiver before demodulation, ΔRF,
- — overall response curve at audio-frequencies of the receiver, including the loudspeaker,
- — the grade of listener satisfaction aimed at and the statistical distribution of such grades;

2. that, if all the results cannot be presented as a function of the above characteristics and parameters, at least some of the results should be presented with respect to the following values:

Δf (kHz)	k	b (kHz)	Programmes (wanted and unwanted)	Input voltage, RF, of the wanted signal (mV)	ΔRF (kHz)	Overall frequency response	Listener satisfaction (%)
0 (1) 5 9 10	0·8	±10	Light music	0·1–1 (2)	5 at the 6 dB points	Flat within ±3 dB up to 2·5 kHz	50

(1) Within ±20 Hz.

(2) The radio-frequency input voltage should be chosen in such a way that the protection ratios are not significantly affected by non-linearities within the radio-frequency and intermediate-frequency stages of the receiver.

3. that the measuring technique should be indicated (subjective or objective, stable or fluctuating wanted and interfering signals, etc.).

RECOMMENDATION 414

DIRECTIONAL ANTENNAE

Presentation of antenna diagrams

(Question 14/10)

The C.C.I.R. (1963)

UNANIMOUSLY RECOMMENDS

1. that the new diagrams to be published in the C.C.I.R. Book of Antenna Diagrams be presented in the same form as at present, but that the curves of equal field strength be expressed in dB referred to the maximum, instead of in percentages of power;

2. that the curves of equal field strength be determined by the following values (in dB below the maximum):

$$0, 1, 2, 3, 4, 6, 8, 10, 13, 16, 20, 25, 30, 40 \text{ and } \infty$$

or at least for some of these values, preferably:

$$0, 3, 6, 10, 20, 40 \text{ and } \infty.$$

RECOMMENDATION 447

SIGNAL-TO-INTERFERENCE RATIOS IN AMPLITUDE-MODULATION SOUND BROADCASTING

Definitions

The C.C.I.R. (1966)

UNANIMOUSLY RECOMMENDS

that, when considering problems of interference in sound broadcasting, the following definitions should be used:

1. *the audio-frequency signal-to-interference ratio* is the ratio, expressed in dB, between the values of the voltage of the wanted signal and the voltage of the interference, measured under specified conditions, at the audio-frequency output of the receiver.

   This ratio corresponds closely to the difference in volume of sound (expressed in dB) between the wanted programme and the interference.

2. *The audio-frequency protection ratio* is the agreed minimum value of the audio-frequency signal-to-interference ratio considered necessary to achieve a subjectively defined reception quality.

   This ratio may have different values according to the type of service desired.

3. *The radio-frequency wanted-to-interfering signal ratio* is the ratio, expressed in dB, between the values of the radio-frequency voltage of the wanted signal and the interfering signal, measured at the input of the receiver under specified conditions.

   For example, in the case of wanted and interfering transmissions of the classical type (carrier with double sideband), the chosen values will be the effective radio-frequency voltages that correspond to the wanted and interfering carriers.

4. *The radio-frequency protection ratio* is the value of the radio-frequency wanted-to-interfering signal ratio that enables, under specified conditions, the audio-frequency protection ratio to be obtained at the output of a receiver.

These specified conditions include such diverse parameters as spacing Δf of the wanted and interfering carrier, emission characteristics (type of modulation, modulation depth, etc.), receiver input and output levels as well as the receiver characteristics (selectivity and susceptibility to cross-modulation, etc.).

RECOMMENDATION 448

SOUND BROADCASTING IN BANDS 5 (LF) AND 6 (MF)

Radio-frequency protection ratio

(Study Programme 25A/10)

The C.C.I.R., (1966)

CONSIDERING

that frequency assignment conferences should base their work on a generally agreed value of radio-frequency protection ratio which may also be applied in the examination of cases of interference;

UNANIMOUSLY RECOMMENDS

that the radio-frequency protection ratio (as defined in Recommendation 447), for co-channel transmissions ($\pm$ 50 Hz), in bands 5 (LF) and 6 (MF), should be 40 dB when both the wanted and the unwanted signals are stable (ground-wave).

When the wanted signal is stable and the unwanted signal fluctuates (sky-wave), the radio-frequency protection ratio should be 40 dB at midnight for at least 50% of the nights of the year.

ANNEX

This value of 40 dB takes account of the subjective effect of short-term fluctuations of the unwanted signal (see also Report 298-2, § 2.2 and Report 264-2, § 3.2) and corresponds to the ratio of the wanted field-strength and the annual median value of the hourly medians of the interfering field-strength at 2400 hours local time at the midpoint of the path.

The protection so defined is provided;

— for 50% of the nights at 2400 hours local time;

— for more than 50% of the nights between sunset and midnight and between 0300 hours and sunrise; and

— for 100% of the days during daylight hours.

Note 1. — The minimum field strength to which this protection ratio of 40 dB applies varies in the different regions and with frequency. Within the European zone this minimum is of the order of 1 mV/m.

Note 2. — In the United States of America, when the wanted and unwanted signals are stable (ground-wave), the radio-frequency protection ratio for co-channel transmissions is 26 dB. When the unwanted signal is fluctuating (sky-wave) the same protection ratio is applied for 90% of the nights of the year, computed for the second hour after sunset. The minimum field strength protected is either 100 or 500 μV/m, depending upon the class of service.

RECOMMENDATION 449-1

AMPLITUDE-MODULATION SOUND BROADCASTING

Radio-frequency protection-ratio curves

(Question 25/10)

The C.C.I.R. (1966 – 1970)

UNANIMOUSLY RECOMMENDS

that once a value for the co-channel radio-frequency protection ratio (which is equal to the audio-frequency protection ratio) has been agreed upon, then the radio-frequency protection ratio, when expressed as a function of the carrier-frequency spacing between a stable wanted signal and a stable or fluctuating unwanted signal is given by:

— curve A of Fig. 1, when a limited degree of modulation compression is applied at the transmitter input, such as in good quality transmissions;

— curve B of Fig. 1, when a high degree of modulation compression (at least 10 dB greater than in the preceding case) is applied by means of an automatic device.

The curves A and B are valid only when the wanted and unwanted transmissions are compressed to the same extent.

ANNEX

The shape of the radio-frequency protection-ratio curves depends on the receiver selectivity and also on the ratio of the energy of the carrier and of the sidebands. This latter phenomenon is most important between 250 Hz and 5 kHz approximately, where the disturbance is essentially due to the whistle produced by the carrier-frequency beat. The shape of the curves therefore depends on the average modulation depth and on the dynamic compression of the modulation signals.

Curve A represents average values obtained by tests made with various receivers and with " average " degrees of modulation compression, such as that currently applied in the studios, i.e. with compression permitting a maximum dynamic range of at least 30 dB.

Curve B applies to the use of compression at least 10 dB higher than in the preceding case.

It should be noted that, in some circumstances, listeners are able to reduce the interfering effect of an unwanted transmission spaced by more than 3 kHz approximately, by adjusting their receiver (slight detuning, selectivity control, tone control, etc.). Under these conditions the curves of the attached Figure are no longer applicable for spacings of more than about 3 kHz. However, this practice leads to distortion and cannot be used when approximately equally strong interfering emissions are present, on both sides of the wanted carrier frequency. Moreover, many receivers are not equipped with a selectivity control or a tone control.

Note 1. — In addition to the relative radio-frequency protection ratios given in this Recommendation there are other factors of importance in determining optimum frequency-spacings (see Question 25/10).

Note 2. — Caution should be exercised when relative values of radio-frequency protection ratio beyond —50 dB are obtained from the curves because, in practice, non-linear distortion originating in the transmitter may lead to poorer protection than indicated.

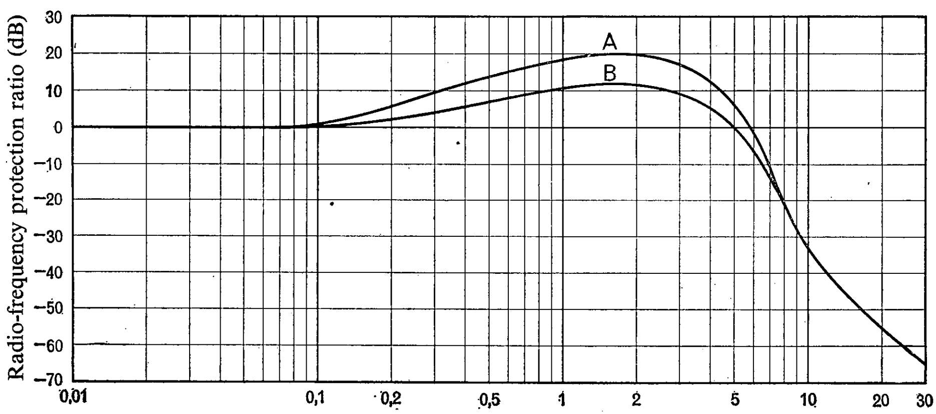

FIGURE 1

Relative value of the radio-frequency protection ratio as a function of the frequency separation between a stable wanted and a stable or fluctuating unwanted signal

REPORT 32-1 *

BROADCASTING IN BAND 7 (HF)

Directional antenna systems

(Question 14/10)

(1953 – 1966)

1. Reduction of subsidiary lobes

Question 14/10 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; using 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 beamwidth 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°.

* This Report was adopted unanimously.

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 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 antenna 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 antenna;
— 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 antenna;
— by limiting radiation in all directions, other than those comprised in the main lobe, to a certain proportion of that given by an omnidirectional antenna.

Tests have been carried out in Italy (Doc. X/49), 1963–1966, with an array of HR5/4/1·5 dipoles with reflectors in which each stack of dipoles is fed separately. The five feeders are so adjusted as to reduce the amplitude of the subsidiary lobes. Measurements showed that the reduction was substantial (about 8 dB). This property is maintained when the main lobe is slewed; the largest subsidiary lobe is then very greatly reduced (15 dB for a 18° slew of the main lobe). The whole array remains simple and the increase in the cost price is slight.

Type HR4/4 antennae have recently been manufactured in France. Their special feature is that the reflector is fed, an arrangement which makes it possible to adjust accurately the voltage amplitudes and phases in the arrays, back and front. Measurements of the pattern from a helicopter showed that it resembled the theoretical patterns very closely (nulls about 40 dB). Compared with systems with passive reflectors, the new arrays have a larger bandwidth and are more easily adjusted.

2. Actual protection obtained with directional antennae

The United Kingdom and the Republic of South Africa have carried out an experimental study of the real protection at a great distance by the use of directional antennae in band 7 (HF) (Doc. X/15 (United Kingdom), Bad Kreuznach, 1962 and Doc. X/221 (United Kingdom), Geneva, 1963). This was done by comparing, in South Africa, the field strength produced by two transmitting antennae located at the same and at different sites in the United Kingdom, directed towards South Africa and South Asia respectively. Frequencies in the 21 MHz broadcasting band were used. A system of simultaneous reception with signal strength recordings enabled the effects of short-term propagation variations to be reduced to a minimum and a large number of measurements were made to take account of longer-term variations.

It was observed that the real protection provided by the transmitting antennae at the same site was, under these conditions, about 22·5 dB (average value), as compared with a protection of 19 dB calculated on the basis of Recommendation 80. The protection deduced from the theoretical antenna characteristics was about 38 dB.

Using transmitting antennae at different sites, which were separated by 250 km, the real protection as measured was 21·3 dB (average value), as compared with a protection of 16 dB calculated on the basis of Recommendation 80. The protection deduced from theoretical antenna considerations was in this case about 35 dB.

The difference between the measured value and that calculated on the basis of Recommendation 80 is considered to be sufficiently small to establish the validity of the Recommendation in these particular cases.

Doc. X/124 (United Kingdom), 1963–1966, describes a further experiment carried out between the United Kingdom and the Federal Republic of Germany over medium distances of about 1000 km.

The field strength measured at the receiving station indicated that in only one of five cases was the real protection greater than the theoretical protection. In all other cases the real protection was 1 to 7 dB less than the theoretical value.

On the other hand, the real protection was greater than that determined on the basis of Recommendation 80 by 3 dB, 6 dB and 9 dB in three cases, whilst it was 2 dB and 3 dB less in the remaining two cases.

The protection measured on these particular tests was considered sufficiently close to that obtained by the application of Recommendation 80 to confirm the validity of the Recommendation for medium distances.

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REPORT 297-2 *

BROADCASTING IN BAND 7 (HF) **

Necessary bandwidth of emissions

(1948 – 1956 – 1959 – 1963 – 1966 – 1970)

1. Introduction

Listening tests have been made in connection with this problem on the quality of reception obtainable on short waves and the effects of a reduction of the necessary bandwidth. From these tests, it has been deduced that, although there will be some loss in quality if the audio-frequency band is limited to a highest modulating frequency of 6400 Hz, this loss is not serious. Tests have also been made in which the audio-frequency band has been restricted to a highest modulating frequency of 5000 Hz, when, however, the loss in quality becomes quite noticeable.

2. Causes of unsatisfactory reception

One of the main causes of unsatisfactory reception is the presence of heterodyne interference between the sidebands of different stations or between the sidebands of the transmission of one station and the carrier-frequency of a different station. To some extent, this type of interference can be offset by the listener, who can so adjust his receiver that the interference is either eliminated or reduced.

3. Conclusions

3.1 Unless, in specific instances, it is clearly necessary and effective for eliminating interference, the suppression of desirable portions of the occupied bandwidth should be avoided. It is, therefore, considered desirable that the normal bandwidth of the modulating frequencies should not exceed 6400 Hz.

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 over-modulation, with its inherent production of spurious frequencies.

3.2 At the present time, and with carrier-frequency separation of 10 kHz, there is no evidence that interference will be caused to the average receiver, by the transmission of normal signal intensities in those portions of the sidebands 5 to 6·4 kHz from the carrier-frequency. It does not appear that a reduction in the radio-frequency signal-to-interference ratio will change this conclusion, as far as present types of receiver are concerned. However, the use of pre-emphasis, more sensitive receivers and modified signal protection ratios, or a combination of these factors, may cause the transmission of energy at modulating frequencies, up to 5000 Hz and 6400 Hz respectively, to assume a new importance.

3.3 The results of investigations in the effects on reception of limiting the bandwidth of emission for broadcasting in bands 5 (LF) and 6 (MF) (Report 457) suggest that it is necessary to carry out further tests using modern HF broadcasting receivers.

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* This Report was adopted unanimously.

** Report 457 deals with the corresponding problems for broadcasting in bands 5 (LF) and 6 (MF).

REPORT 298-2 *

PROTECTION RATIOS FOR AMPLITUDE-MODULATION SOUND BROADCASTING

(1963 – 1966 – 1970)

1. Introduction

This Report is a summary of the information available on the subject of protection ratios for amplitude-modulation sound-broadcasting services.

The protection ratios quoted refer, in all cases, to the ratios at the input to the receiver, no account having been taken of the effect of using directional receiving antennae.

The values of protection are required to be known, as they serve as basic data for use in frequency-assignment conferences and as basic reference data for the appraisal of new techniques or procedures to be introduced, such as:

— compatible single-sideband modulation, Study Programmes 25A/10 and 25B/10;

— reduction of radiated bandwidth, Question 25/10;

— use of the sky-wave to increase the service area, Study Programmes 25C/10 and 25D/10;

— use of filter devices at the receiver;

— general studies on broadcasting coverage, Study Programme 25F/10.

A great amount of research work has been carried out since the beginning of broadcasting, but, in view of the development of technique since then, this Report is confined to results obtained after 1948.

Docs. X/16 (U.S.A.) and X/42 (Federal Republic of Germany), 1966–1969 and Report 457 deal with the effect of a limitation of the necessary bandwidth of emission on radio-frequency protection ratios.

2. Data available on protection ratios

The curves reproduced in Report 302 represent the data at present available on the subject of Question 27/10 (formerly 1/XII) and Study Programme 27C/10 (formerly 1C/XII) and refer principally to the protection ratios required to provide an acceptable broadcasting service in the Tropical Zone in the shared bands. Further information on protection ratios may be found in a paper [1] published in the Federal Republic of Germany and in Docs. X/13 (India), and X/20 (U.S.A.), Bad Kreuznach, 1962, in Doc. 218 (France), Geneva, 1963 and also in Doc. X/36 (France), 1963–1966.

2.1 *Techniques for measuring the protection ratio*

The lack of standardized measuring techniques has led to wide differences in the published results. For example, some of the figures and published curves presented relate to measurements made with limited types of wanted and unwanted programme material, whilst others cover a much wider range.

To overcome the difficulties resulting from the large number of parameters associated with subjective methods of measurement, an objective method has been developed for determining radio-frequency wanted-to-interfering signal ratios (see Report 399).

When the audio-frequency protection ratio has been determined by subjective methods, it is then possible to obtain the corresponding radio-frequency protection ratios by purely objective means.

* This Report was adopted unaminously.

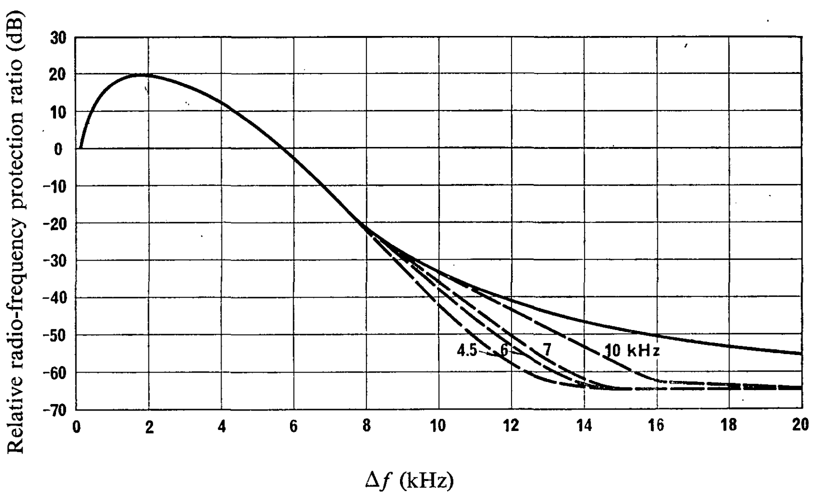

FIGURE 1

Relative radio-frequency protection ratio curve based on the weighting network of C.C.I.T.T. Recommendation P.53

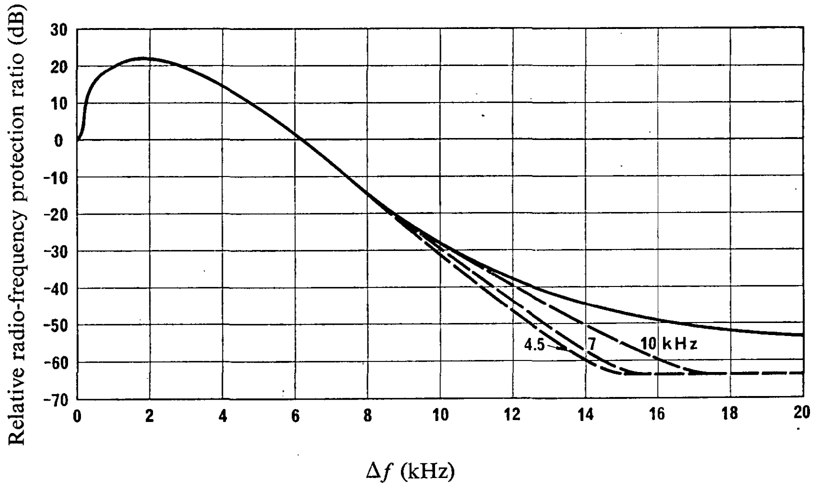

FIGURE 2

Relative radio-frequency protection ratio curve based on the weighting network of Recommendation 468

2.2 *Radio-frequency protection ratios for ground-wave services*

2.2.1 *Stable wanted and interfering signals (ground-wave signal interfered with by another ground-wave signal)*

In Recommendation 448, a value of 40 dB is given for use on hectometric and kilometric waves for co-channel transmissions.

The values of protection ratios as indicated in Recommendations 448 and 449 (curve A) were adopted by the African LF/MF Broadcasting Conference, Geneva, 1966.

Curves showing the relative value of radio-frequency protection ratio as a function of frequency separation have been derived from information at present available (see Recommendation 449). These curves are based mainly on measurements made in accordance with the objective two-signal method of measurement (see Report 399) which uses a psophometer including a weighting network having characteristics in accordance with C.C.I.T.T. Recommendation P.53.

The C.C.I.R. now recommends the use of a weighting network having a slightly different characteristic. (See Recommendation 468).

Comparative measurements of the radio-frequency protection ratio were carried out in the Federal Republic of Germany (Doc. X/177 (E.B.U.), 1966–1969) with the E.B.U. reference receiver MBF using both weighting networks. Figs. 1 and 2 show the results obtained.

Figs. 1 and 2 also show the results obtained for different limited audio-frequency bandwidths of emission (see Report 457). It should be noted, however, that the full improvement in protection resulting from bandwidth limitation can only be obtained when the non-linearity of the transmitter is small enough.

2.2.2 *Stable wanted and fluctuating interfering signal*

2.2.2.1 *Short-term fading*

Short-term fading of the interfering signal modifies the character of the disturbance felt by the listener: if, for a given audio-frequency signal-to-interference ratio, the interfering signal is made to fluctuate, the disturbance is subjectively felt to be more severe. Docs. X/5 (E.B.U.), X/31 (Federal Republic of Germany) and X/36 (France) indicate that, to obtain the same degree of satisfaction of the listener, the protection must be increased by about 5 dB in the latter case.

In Recommendation 448, this value has been incorporated in the radio-frequency protection ratio.

2.2.2.2 *Long-term field-strength variations*

Report 264-1, § 2.5, gives a formula permitting the determination of the ratio between two fluctuating field strengths transmitted by the ionosphere.

In the case under consideration, this formula becomes, with some simplifications of form:

$$R(T) = F_{ou} - F_{on}(50) - \delta(100 - T) - \Delta_H(50) \qquad (1)$$

where

$R(T)$ is the ratio (in dB) of the two field strengths exceeded during $T\%$ of the nights in a year;

F_{ou} is the field strength of the ground-wave of the wanted signal;

$F_{on}(50)$ is the field strength of the ionospheric wave of the unwanted signal at midnight (local time) at the mid-point of the propagation path, which is exceeded during 50% of the nights in a year;

$\Delta_H(50)$ is the correction factor to be applied to field-strength F_{on} to take into account the time at the mid-point of the path;

$\delta_H(T)$ is the correction factor to be applied to field-strength F_{on} to take into account the percentage T of the nights in a year, at H hours (local time) at the mid-point of the path.

The values of $\Delta_H(50)$ and δ_H are given respectively in Figs. 4 and 5 of Report 264-1 as far as the European Broadcasting Area is concerned.

To ensure protection corresponding to a protection ratio of A(dB), the condition

$$A \leqslant R(T) \tag{2}$$

must be satisfied.

2.3 *Protection ratios for sky-wave services*

A characteristic of the sky-wave service is that propagation effects usually bring about a degradation of the received signal quality, e.g., distortion due to selective fading. Because of these factors, it is considered that lower values of protection ratios should be applied to a sky-wave service as compared with a ground-wave service, the precise values depending upon whether the service is a primary one, as for broadcasting in band 7 (HF), or a secondary one, as for broadcasting in bands 5 (LF) and 6 (MF), where the primary service is normally provided by the ground wave.

However, there is at present insufficient information available on this aspect of broadcasting and Administrations are strongly urged to initiate appropriate studies.

2.4 *Data used by the I.F.R.B.*

In its technical examination of frequency notifications, according to the terms of Article 9 of the Radio Regulations, Geneva, 1959, the I.F.R.B. uses the figures for protection ratios and receiver discrimination contained in its own Technical Standards, Series A, Third Edition, 1965.

3. Subjective assessment of the quality of reception

Doc. X/53 (U.S.S.R.), Bad Kreuznach, 1962, gives the results of statistical and subjective tests carried out in the U.S.S.R., on the effects of distortion and interference in a broadcast channel.

The tests were performed using a statistical-subjective method, using special equipment which enabled a comparison to be made between an undistorted sound programme and a second programme, into which predetermined levels of distortion had been injected.

The object of these experiments was to determine the perceptibility of distortion and the following groups of listeners participated:

— qualified experts (sound-broadcasting producers),

— observers without special musical education and without training in the observation of distortion.

The results of these experiments were published in the form of graphs, showing the percentage of perceptibility as a function of the level of the distortion or interference injected.

All these tests were made on the basis of a large amount of statistical data. The correctness of the data obtained was checked by the methods of mathematical statistics. Results were given (see Doc. X/53), in terms of:

— linear distortion of different types (at various levels and for different frequency ranges),

— non-linear distortion (cubic, quadratic and "central-cut off" types),

— background noise (sinusoidal),

— white noise.

In the same document, a system of classification for the estimation of quality of reception is given.

Four classes of quality of reproduction are recommended which are established on the basis of the degree of perceptibility of distortion and interference (see Doc. X/53 (U.S.S.R.), Bad Kreuznach, 1962).

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REPORT 299-2 *

COMPATIBLE SINGLE-SIDEBAND TRANSMISSION FOR AMPLITUDE-MODULATION SOUND BROADCASTING SERVICES

(Question 25/10)

(1963 – 1966 – 1970)

1. Proposed methods of generating compatible single-sideband signals

Compatible single-sideband transmission has been the subject of study in several countries, namely, Australia [1], Czechoslovak Socialist Republic, Federal Republic of Germany, Netherlands, People's Republic of Poland, United States of America and the U.S.S.R., as well as in the European Broadcasting Union.

For modulation of a radio-frequency f, by a sinusoidal signal at a frequency F, it can be shown that the required single-sideband signal, with an undistorted envelope, can be formed from a signal with three components f, $(f + F)$ and $(f + 2F)$, as shown in (1):

$$E = \zeta \sin 2\,\pi f t + a \sin 2\pi(f + F)t + (a^2/4\zeta).\, \sin 2\pi(f + 2F)t \qquad (1)$$

of which the envelope amplitude is given by:

$$A = \zeta + (a^2/4\zeta) + a \cos 2\pi\, Ft \qquad (2)$$

At low indices of modulation only two components are required. It is possible also to calculate the degree of phase- (or frequency-) modulation necessary to produce, together

* This Report was adopted unanimously.

with the required amplitude-modulation, the required compatible single-sideband signal. The required phase-modulation is given by:

$$\varphi = \arc \sin \{[a \sin 2\pi Ft + (a^2/4\zeta) \sin 4\pi Ft] / [\zeta + (a^2/4\zeta) + a \cos 2\pi Ft]\} \quad (3)$$

In spite of a similar theoretical background, workers in the various countries have worked along different lines to bring about results which are very close to the theory.

1.1 *In the United States of America* [2], a signal is generated by passage of a single-sideband signal through two different non-linear circuits. By a suitable combination of addition and mixing procedures, a phase-modulation is achieved which is appropriate for eliminating the unwanted sideband, and which gives a close approximation to the waveforms of the three-component signal.

1.2 *In the Netherlands* [3], it was observed that it would be possible to achieve the necessary three-component signal by squaring a full-carrier single-sideband signal. However, a correction must be applied to neutralize intermodulation distortion.

1.3 *In the Czechoslovak Socialist Republic* [4], a signal is obtained, which is very nearly a single-sideband signal, from the original audio-frequency input by a combination of a non-linear network and a phase-shift network. Suppression of the unwanted sideband is then improved by the use of negative feedback.

1.4 *In the U.S.S.R.* [5, 6, 7], a compatible single-sideband signal is generated by dividing the audio-frequency input signal along two paths: the first path, through a delay-line and an amplitude-modulator; the second, through a special integrating network and a phase-modulator.

2. Standardization aspects

The standardization of a compatible single-sideband system should take account of the following factors:

2.1 It must satisfy the provisions of Recommendations 328-2 (out-of-band radiation for amplitude-modulation emissions) and 329-2 (spurious emissions).

Moreover, it is essential that out-of-band radiation should not exceed that specified for existing double-sideband systems, and that this condition be maintained, in practice, under normal conditions of operation. In particular, no system should be standardized which requires constant supervision of the working transmitter to satisfy this stipulation.

2.2 It is necessary to define the audio-frequency response. It is likely that different definitions will be needed for:

— broadcasting in band 5 (LF) and band 6 (MF),

— broadcasting in band 7 (HF).

2.3 The extent (in decibels) to which the unwanted sideband should be reduced.

2.4 To avoid the need for highly selective filters, suppression of the unwanted sideband below 300 Hz should not be required.

2.5 In connection with § 2.4, there is a possible advantage in permitting double-sideband or reduced sideband transmission up to 750 Hz. However, this transmission may lead to increased co-channel interference on account of fixed beat-frequencies.

2.6 Distortion and interference in normal types of receiver should be of the same order as those acceptable in normal double-sideband broadcasting.

2.7 It is not necessary to use always the same sideband (upper or lower). Doc. X/33 (France), Bad Kreuznach, 1962, gives a channel arrangement (“ tête-bêche ” channels), which would permit either an increase in the number of channels or an improvement in the quality of services, depending upon the interpretation given to the various technical data relating to the problem.

3. Harmonic distortion of the envelope of the modulated radio-frequency signal

3.1 In the People's Republic of Poland theoretical and experimental investigations have been carried out on the sensitivity of some compatible single-sideband systems [2, 3] to harmonic distortion of the envelope of the modulated radio-frequency signal, caused by transmission of the signal over lines, the amplitude-frequency and phase-frequency transfer characteristics of which are imperfect.

The results of these investigations (Doc. X/47, 1966–1969) suggest that both the systems considered are more sensitive to harmonic distortion than double-sideband systems.

3.2 In the People's Republic of Poland, investigations were carried out of the harmonic distortion produced in the envelope of the compatible single-sideband and double-sideband emissions when they pass in the receiver through a piezo-ceramic, intermediate-frequency bandpass filter (Doc. X/49, 1966–1969).

The results of a comparative analysis show, that the values of harmonic distortion in the envelope of the compatible single-sideband signal are similar to those for the double-sideband signal. For this reason, broadcast receivers equipped with properly designed piezo-ceramic intermediate-frequency bandpass filters are more suitable for reception of compatible single-sideband emission, than existing receivers with conventional types of intermediate-frequency filter.

3.3 Doc. X/48, 1966–1969, gives information concerning the preliminary investigations carried out in the People's Republic of Poland, into the harmonic distortion of the modulated signal envelope. This distortion originated in electro-mechanical filters (designed for conventional single-sideband receivers), when the compatible single-sideband or double-sideband signal passed through the filter.

The results of these investigations show that the harmonic distortion in the compatible single-sideband signal at the output of this filter is greater than in a double-sideband signal.

3.4 Similar theoretical studies [8, 9, 14] and experimental investigations [10] on a compatible single-sideband system [2] have been carried out in the Federal Republic of Germany. The results show that in current type receivers the amplitude and phase responses of the pass-band filters cause higher harmonic distortion to a compatible single-sideband signal than to a double-sideband signal.

3.5 Harmonic distortion when receiving sky-wave transmissions over path lengths of up to 600 km has been studied by the European Broadcasting Union (Doc. X/204, 1966–1969) [16].

Once again the distortion factor due to receiver pass-band filter effects was 2·5 to 4 times higher for compatible single-sideband transmissions [2] than for double-sideband transmissions as was the case with ground-wave reception. In the sky-wave service area the distortions were still higher, but the ratio of the distortion factors of the received compatible single-sideband and double-sideband signals remained virtually unchanged.

3.6 With current types of receiver the compatible single-sideband systems described do not appear to have any important advantages over the double sideband system. In particular, the quality of the received compatible single-sideband signal is often inferior to that of a double-sideband signal for both ground-wave and sky-wave reception. It is, therefore, not appropriate to use these systems unless reception quality is not an essential factor.

4. Other points of general interest

4.1 Measurement results obtained in the Federal Republic of Germany (Doc. X/32, 1963–1966) [10] with the system described in [2] indicate that correct operation of the automatic gain control in current types of double-sideband receiver depends on the modulation depth and in practice this leads to dynamic distortion.

4.2 In present types of receivers, where the intermediate-frequency bandwidth limits the audio-reproduction that can be achieved, the use of compatible single-sideband may permit an increase of up to 1·5 to 2 kHz in the audio-frequency bandwidth, as long as no change in channel allocation is made.

The extended audio-frequency bandwidth can only be obtained when the receiver is detuned by an amount equal to the extension. This measure, however, gives rise to additional non-linear and dynamic distortion [9, 10].

4.3 The effect of the introduction of compatible single-sideband operation on the service area of a transmitter depends on the factors which limit this area. If the area is limited by interference from other transmitters, measurements of radio-frequency wanted-to-interfering signal ratio would clarify the problem. If the area is limited only by noise, the additional energy in the wanted sideband may assist in increasing the service area.

4.4 In a compatible single-sideband system, it is important that correct tuning of the receiver shall not be made appreciably more difficult than that of a current double-sideband receiver.

4.5 From theory it is clear that demodulation techniques using a reinserted carrier cannot be used for the demodulation of compatible single-sideband signals.

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REPORT 399-1 *

AMPLITUDE-MODULATION SOUND BROADCASTING

Objective two-signal methods of measurement of radio-frequency wanted-to-interfering signal ratios

(1966 – 1970)

1. Introduction

Numerical values of radio-frequency protection ratios for amplitude-modulated sound broadcasting have been suggested from time to time by various authorities and agreed values of protection ratios are needed both for the use of future broadcasting conferences and for the solution of frequency assignment problems for broadcasting in bands 5 (LF), 6 (MF) and 7 (HF).

It appears to be essential, therefore, that future work connected with protection ratios should be carried out under strictly defined test conditions to produce exact numerical values against which the results obtained by different authorities may be compared.

The terms defined in Recommendation 447, namely:

— the audio-frequency signal-to-interference ratio,

— the audio-frequency protection ratio,

— the radio-frequency wanted-to-interfering signal ratio, and

— the radio-frequency protection ratio,

are all interdependent, the audio-frequency signal-to-interference ratio at the receiver output being directly related to the radio-frequency wanted-to-interfering signal ratio at the receiver input. This relationship depends on a number of technical factors including carrier-frequency spacing, type and depth of modulation, transmission bandwidth, amplitude of receiver input voltage and the characteristics of the receiver itself.

The need to establish a minimum quality of reception leads to a minimum audio-frequency signal-to-interference ratio to be protected, that is to say, to the audio-frequency protection ratio. The relationship between the audio-frequency and radio-frequency protection ratios is determined by the transmission parameters and the receiver characteristics.

2. Possibilities and limitations of objective methods of measurement

The audio-frequency protection ratio is generally determined by subjective listening tests with several observers, who are presented with various types of broadcast programmes with different forms of interference. If, as is usual, the radio-frequency wanted-to-interfering signal ratio is plotted for different values of the carrier-frequency spacing, there is obtained,

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* This Report was adopted unanimously.

taking into account the various technical parameters, a great number of curves. In addition to the technical parameters, different types of unwanted and wanted programmes have a considerable effect on the results. Moreover, for statistical reasons, it is necessary to use a fairly large number of observers and consequently the numerous possible combinations of the test conditions lead to experiments on a scale which, in practice, demands a drastic reduction of the number of variables.

It is desirable, therefore, to replace, wherever possible, subjective tests by objective measurements where a standard noise signal may be used to simulate the wanted and unwanted programmes and where the observers can be replaced by a measuring instrument.

It is impossible, in theory, to obtain numerical values for radio-frequency protection ratios by means of objective measurements alone. The measuring method proposed merely produces quantitative information concerning the relationship between different audio-frequency signal-to-interference ratios and the corresponding radio-frequency wanted-to-interfering signal ratios. To determine the radio-frequency protection ratio, it is necessary to decide first of all upon a basic audio-frequency protection ratio corresponding to the desired reception quality.

3. Description of the method

3.1 *Principle*

The objective method developed by the European Broadcasting Union and used by broadcasting organizations and Administrations in the Federal Republic of Germany, France, and the Netherlands, is essentially a psophometric two-signal method which consists in modulating successively, with a given modulation depth, the wanted and the interfering transmitter by a standard coloured noise signal, the spectral amplitude distribution of which corresponds to modern dance music (in France a mixture of 16 types of programme has been used).

The interference effect is measured at the audio-frequency output of the receiver by means of an international standard noise voltmeter (psophometer). The reference value used to define the audio-frequency signal-to-interference ratio is that which is measured at the audio-frequency output of the receiver with the same noise voltmeter, when the wanted transmitter is modulated with the " coloured " noise, while the unwanted transmitter is switched off.

The psophometric method is described in more detail in [3, 4 and 5].

3.2 *Psophometer*

The noise voltmeter used to measure the wanted and interfering signals at the output of the receiver consists of an r.m.s. voltmeter with defined dynamic characteristics and an added filter which modifies the interfering frequencies according to their subjective interference effect [1].

3.3 *Noise signal for modulating the signal generators*

Two conditions must be fulfilled by the standardized signal to simulate programme modulation:

— its spectral constitution must correspond to that of a representative broadcast programme;

— its dynamic range must be so small as to result in a constant, unequivocal reading on the psophometer.

The amplitude distribution of modern dance music was taken as a basis, as it is a type of programme with a considerable proportion of high audio-frequencies, which occur most frequently.

Curve A of Fig. 2 shows the spectral amplitude distribution of the corresponding noise signal.

The spectrum beyond the required bandwidth of the standardized coloured noise should be restricted by a low-pass filter having a cut-off frequency of, for example, 10 kHz, and a slope of 60 dB/octave. The audio-frequency amplitude/frequency characteristic of the modulation stage of the signal generator shall not vary by more than 2 dB up to the cut-off frequency of the low-pass filter.

For measurements with bandwidths appropriate to the system, the low-pass filter shall have a corresponding cut-off frequency with the same slope.

3.4 *Measuring arrangements*

Fig. 1 shows a schematic diagram of the measuring arrangements, in which the elements of fundamental importance are drawn in thick outlines. The other elements are measuring and control devices that are required for putting the investigations into practice, or for facilitating them.

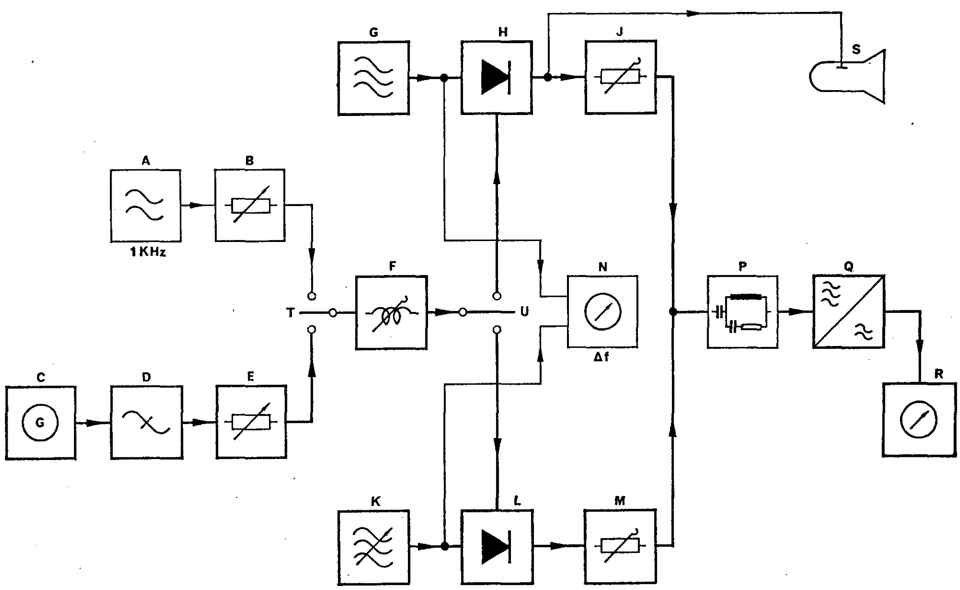

FIGURE 1

Schematic of the measuring apparatus

A : 1 kHz audio-frequency generator (for calibration of the depth of modulation)
B : calibrated attenuator
C : noise generator
D : noise-shaping filter (see Fig. 3)
E : calibrated attenuator
F : low-pass filter
G : signal generator (wanted signal)
H : modulator
J : calibrated attenuator
K : signal generator (interfering signal)
L : modulator
M : calibrated attenuator
N : frequency meter for measuring the frequency difference between signal generators G and K
P : artificial antenna (according to C.C.I.R. Recommendation 331)
Q : receiver under test
R : psophometer according to C.C.I.T.T. Recommendation P.53 (r.m.s. voltmeter with frequency weighting)
S : oscilloscope (for monitoring purposes)
T : selector switch for the modulation (1 kHz tone or standardized noise signal)
U : changeover switch for the modulation (signal generator G or K)

3.5 *Depth of modulation of the test transmitters*

The depth of modulation of the wanted or interfering signals is determined by the following procedure. The signal generator is first modulated to a depth of 50% with a sinusoidal tone from the generator A, adjusted by means of the attenuator B and verified by oscilloscope S at the radio-frequency outputs of modulators H or L, and the required audio-frequency voltage is measured at the modulator inputs (switch U) by means of the psophometer R. The amplitude of the noise signal (C + D), which is measured with the same measuring instrument R, should then be adjusted (by means of the attenuator E) to read 6 dB lower than the value obtained with the sinusoidal signal. Owing to the sluggishness of the psophometer, this corresponds to a depth of modulation of 50% measured with a programme-meter with quasi-peak indication. Deeper modulation is not appropriate, because, on account of its very small dynamic range, the noise would have a more disturbing effect than any real programme.

3.6 *Audio-frequency signal-to-interference ratio*

The signal generator (wanted signal) (G + H + J) modulated with noise according to §§ 3.3 and 3.5, produces a signal at the audio-frequency output of the receiver under test Q, which represents—measured with the psophometer R—the reference level " zero ". The noise modulation is then transferred by means of the switch U, from the audio-frequency input of the modulator H of the signal generator (wanted signal) to the audio-frequency input of the modulator L of the signal generator (interfering signal). After suppression of the wanted signal, the radio-frequency level of the signal generator (K + L + M) is then adjusted so that the unwanted voltage, as measured by means of the psophometer R at the receiver output results in the required audio-frequency signal-to-interference ratio, for example, 20, 30 or 40 dB below the reference value.

3.7 *The radio-frequency level of the wanted signal at the receiver input*

The radio-frequency output voltage of the signal generator (G + H + J) should be, to begin with, as small as possible, so that only linear receiver characteristics enter into the measurement. The level of the unmodulated signal generator should, however, be chosen high enough for the noise voltage (mostly the inherent noise of the receiver), measured at the audio-frequency output of the receiver, to lie at least 3 dB below the noise voltage in the presence of the modulated interfering signal according to § 3.6. The radio-frequency output of the signal generator (G + H + J) should then be increased in steps to include the non-linear characteristics of the receiver (cross-modulation).

3.8 *Influence of non-linear distortion in the signal generators*

The non-linear distortion occurring during the modulation process in the signal generator has components which widen the radio-frequency spectrum and thus give rise to increased radio-frequency wanted-to-interfering signal ratios in the region of the adjacent channel and adjacent-channel-but-one.

The non-linear distortion in the signal generators should not, therefore, exceed 1% to 2%.

4. Receivers

In principle, the method of measurement described may be employed with any given receiver providing the characteristics of the receiver used are clearly stated, together with the measurement results. As it is not possible to define an average receiver representing all types of receiver now in use or likely to become available in the future, it is appropriate to use reference receivers with well-defined characteristics [3, 4, 5 and 6].

For domestic broadcast receivers, measurements taken at the audio-frequency output of these receivers neglect loudspeaker characteristics and, since the characteristics of the audio-frequency amplifier and loudspeaker are matched to each other, it is advisable to take the measurements at the detector output.

5. Conclusions

The results obtained with the objective method have been compared with the results of corresponding subjective tests in the Federal Republic of Germany [7] and in France [8] and from these tests it has been found that objective measurements give a first approximation to those obtained with the subjective method.

Whilst the subjective method definitely measures the phenomena under study, it is in general less accurate and much more difficult to arrange whereas the objective method is easy to implement and leads to a higher statistical accuracy of results.

However, it should be borne in mind that objective methods only provide information on the relationship between audio-frequency signal-to-interference ratios and radio-frequency wanted-to-interfering signal ratios. The audio-frequency protection ratio can only be determined on the basis of subjective tests.

On the other hand, the objective method is particularly suitable for the study of the influence of various technical factors such as the transmitted bandwidth, effect of compressors, limiters and similar devices, receiver selectivity, and of new techniques such as compatible single-sideband modulation. In the latter case, it is necessary to use appropriate modulation characteristics during measurements.

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ANNEX

Filter circuit for obtaining the signal corresponding to the standardized " coloured " noise

The double-signal objective method of measuring radio-frequency protection ratios [3, 4, 5] makes use of a standardized noise signal whose spectral composition is well defined by Fig. 2 (Curve A). It seems to be worthwhile to specify a passive circuit capable of producing the signal in question from a " white-noise " generator.

The characteristics of this filter are shown in Fig. 3. Also reproduced here, as Fig. 2 (Curve B), is the frequency-response characteristic used for verifying the circuit by means of sinusoidal signals. It should be noted that the difference between curves A and B of Fig. 2 is due to the fact that curve A is based on measurements with " one-third octave " filters which pass greater amounts of energy as the bandwidth of the filter increases with frequency.

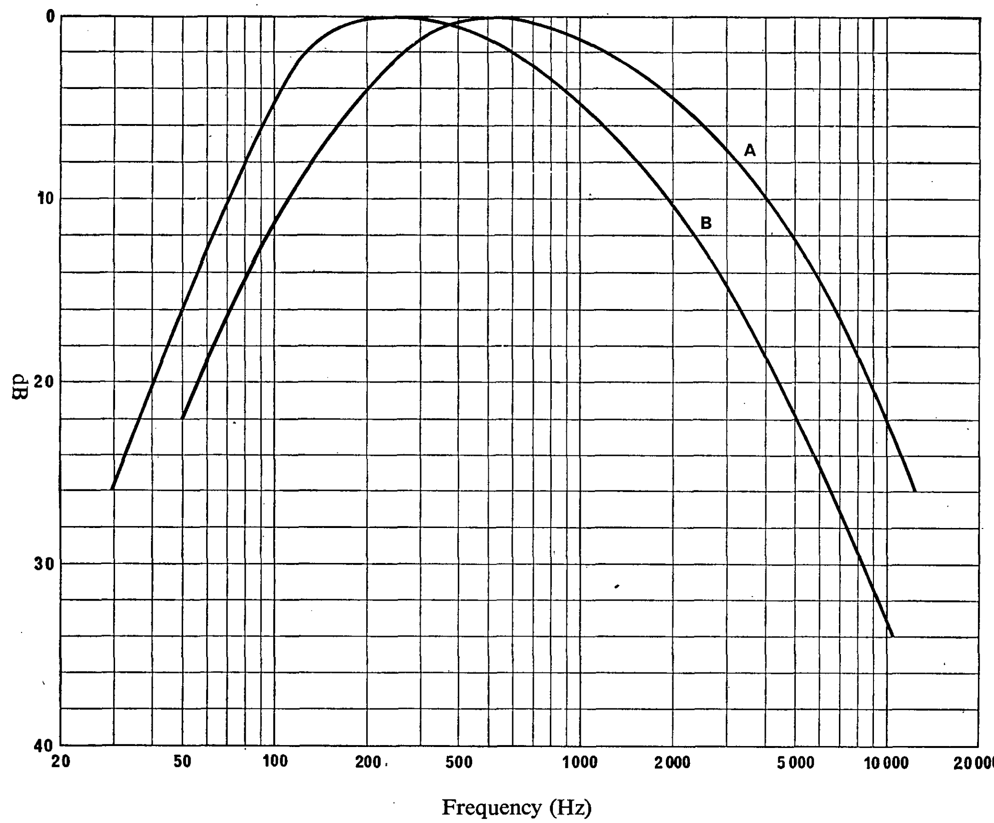

FIGURE 2

Curve A: Frequency spectrum of standardized noise (measured with one-third octave filters)

Curve B: Frequency response characteristic of filter-circuit

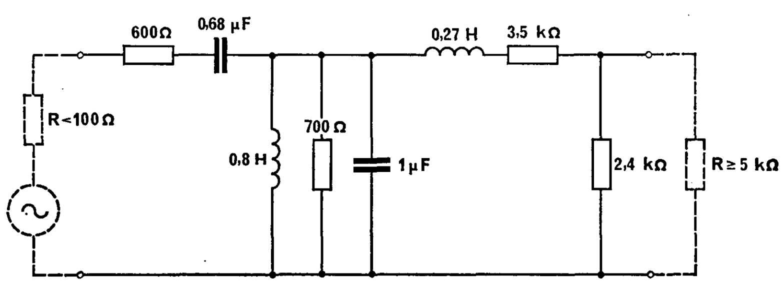

FIGURE 3

Filter-circuit

REPORT 400-1 *

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Broadcasting coverage in band 6

(Study Programme 25F/10)

(1966 – 1970)

1. Introduction

Broadcasting transmitter networks should be planned in such a way that coverage of the required area is provided using the minimum number of frequencies.

From the purely technical standpoint, the service area of each transmitter depends on a number of factors, e.g. transmitter power, minimum field-strength to be protected, radio-frequency protection ratio, distance between transmitters sharing the same channel, channel spacing, ground conductivity and operating frequency.

The service areas vary considerably with the type of service required which may be ground wave by day, ground wave or sky wave by night.

Studies have been carried out in France and in the Federal Republic of Germany in the framework of the activities of the European Broadcasting Union [1, 2, 3]. In these studies one of the main aspects was to examine the influence on coverage of the radio-frequency protection ratio and the distance between transmitters sharing the same frequency.

Initially these studies assumed an infinite plane Earth, but they were later extended to cover the case of a spherical Earth.

2. Coverage factor as a function of distance

In the absence of noise, two transmitters operating on the same frequency with an equal power P (kW), separated by a distance D (km), have a service range R (km) which depends on the radio-frequency protection ratio A (dB), but is independent of the transmitter power. In the presence of noise the service range is also dependent on the transmitter power.

The coverage factor, c, may be defined to be the ratio of the sum of all service areas, s_n, of the individual transmitters operating on the same frequency on a very extensive area S to the total area:

$$c = \Sigma\, s_n/S = (2\pi/\sqrt{3})\,(R^2/D^2).$$

The quantity R^2/D^2 is, thus, proportional to the coverage factor.

To establish curves showing the dependency of $10^3 \times R^2/D^2$ or c, respectively, on the distance D with either A or P as parameters the following conditions were taken as a basis:

- transmitters of equal power;
- ground-wave propagation curves of Recommendation 368-1;
- sky-wave field: annual median value of the hourly median values at midnight;
- sky-wave propagation curves derived from Report 264-2, Fig. 1, extrapolated beyond 3500 km (Fig. 1).

The extrapolation was made in three different ways:

- by extending the curves using formula (1a) of § 2.2 of Report 264-2 (propagation type No. 1);

* This Report was adopted unanimously.

— by halving the mean slope of the existing curves every 500 km from 3500 km onwards (propagation type No. 2);

— by taking an intermediate curve between the first two curves (propagation type No. 3).

Correction factors taking account of the vertical radiation diagram of the transmitting antenna, magnetic dip, sunspot number, etc., were not applied to the field-strength values obtained from the curves of Fig. 1.

Note. — Field-strength measurements carried out in bands 5 (LF) and 6 (MF) in the U.S.S.R. [4, 5, 6] show that, particularly in band 6, substantially higher values of field strength were obtained at distances beyond 2000 km than would be expected from the curves of Report 264-2 extrapolated to about 4500 km. Other measurements taken in various parts of the world [7, 8] show similar trends at distances beyond 3000 km.

3. Results

3.1 *Plane Earth*

The curves in Figs. 2 and 3 for a frequency of 1 MHz are given as examples. Both Figures are based on the assumption that there is only one interfering station and the service range was calculated under the worst condition, i.e. on the straight line connecting the wanted and unwanted transmitter. Both Figures show the dependency of the coverage factor on the distance between transmitters operating on the same frequency.

Fig. 2 is valid when a ground-wave service is limited by sky-wave interference from the unwanted transmitter and when, in the absence of noise, there is no power dependency. The parameter indicated on the curves is the radio-frequency protection ratio A. Also shown in decibels relative to 1 μV/m is the field F_1 of the wanted transmitter at the limit of the service area, for a transmission power of 1 kW with a short vertical antenna. For instance, a point of intersection on a curve shown by long dashes, for $F_1 = 40$ dB, and a curve $R^2/D^2 = f(D)$, for $A = 25$ dB, means that if the transmitters are separated by a distance D km (abscissa of the point of intersection) and for a protection ratio $A = 25$ dB, the field at the limit of the area, where the radio-frequency protection ratio is $\geqslant$25 dB, is 0·1 mV/m.

Fig. 3, which assumes propagation type No. 1, shows the influence of the power P (which is the parameter indicated on the curves) in the presence of noise for a radio-frequency protection ratio $A = 40$ dB as specified in Recommendation 448. The coverage factor c is presented on a logarithmic scale to enable a comparison to be made between the five examples shown:

— ground-wave service interfered by a ground-wave signal (day-time conditions), ground conductivity $\sigma = 3\times10^{-3}$ mho/m;

— ground-wave service interfered by a ground-wave signal (day-time conditions), ground conductivity $\sigma = 1\times10^{-3}$ mho/m;

— ground-wave service interfered by a sky-wave signal (night-time conditions), ground conductivity $\sigma = 3\times10^{-3}$ mho/m;

— ground-wave service interfered by a sky-wave signal (night-time conditions), ground conductivity $\sigma = 1\times10^{-3}$ mho/m;

— sky-wave service interfered by a sky-wave signal (night-time conditions).

It should be noted that the distance D between transmitters sharing the same frequency, range from 100 km to 1000 km in the first and second examples and from 1000 km to 10 000 km in all the others.

Fig. 2 shows that:

— initially the coverage factor decreases as D increases and is smallest at approximately 1500 km. However, in practice, these relatively high coverage factor values at small distances between transmitters cannot be achieved because interference from more than one transmitter is to be expected;

— for distances beyond about 1500 km up to at least 4000 km, the coverage factor increases;

— beyond 4000 km, the variation of the coverage factor depends on propagation conditions. With propagation of type No. 3, the variation is only slight, at least for high radio-frequency protection ratios;

— the general shape of the curves, though varying with the propagation type for distances beyond 3500 km, is practically independent of the conductivity of the soil and the frequency;

— the optimum separation depends considerably on the propagation type but less so on the radio-frequency protection ratio.

Fig. 3 shows that, in the presence of noise:

— the optimum separation between transmitters using the same channel varies considerably with transmitter power;

— the optimum separation is completely different under day-time and night-time conditions;

— the optimum separation is not very different under night-time conditions both for a ground-wave or a sky-wave service;

— the lowest coverage will be obtained when a ground-wave service is interfered by the sky-wave signal of an unwanted transmitter;

— at least with high-power transmitters ($P \geqslant 30$ kW), a sky-wave service would give a coverage similar to that of a ground-wave service at day-time.

3.2 *Spherical Earth*

For interference from sky-wave signals either to a ground-wave or to a sky-wave service, suitable co-channel distances are of the order of the Earth's radius, so that the spherical nature of the Earth must be taken into account. This has been done in [3] where only sky-wave service is considered and where potential interference from the nearest co-channel transmitters, all equally spaced, has been taken into account.

An attempt has been made, therefore, to cover a sphere with a network of equilateral spherical triangles. It can be shown that this can be done by approximating the sphere to a polyhedron. A tetrahedron, octahedron and icosahedron provide surfaces consisting of 4, 8 and 20 equilateral triangles, respectively. These triangles may be developed on to a plane and it is then possible to apply without difficulty a linear channel distribution to this development.

However, when reconstituting the polyhedron, some of the triangles will share sides or apices with other triangles, from which they were separated in the plane development. In those groups of triangles the channel distribution will then no longer necessarily be linear, and consequently restrictions on the use of the channels shown on these triangles will occur. The proportion of these (unusable) triangles with respect to the total number will be at most 40% in the case of the icosahedron, 25% in the case of the octahedron and 50% in the case of the tetrahedron. On the other hand, these triangles may be ignored to a large extent by making use of the fact that dry land occupies only one third of the Earth's surface. It is, therefore, still possible to utilise the results that have already been obtained by considering networks on a plane surface.

Assuming that for the coverage of the land masses about 50% of the triangular surfaces will in fact be used, each channel can be used precisely 0·25 times the number of existing triangular planes. It is now possible to show as a final result the full relationship between the number of transmitters b, co-channel distance D, necessary transmitter power P and coverage factor c, that can be obtained in one single diagram. Fig. 4 shows this result. It should be noted that the absolute value fixed for any one of these parameters determines the values of all the others. When using this Figure one should bear in mind that it can only give an estimation of these relationships.

In an additional study the influence of the radio-frequency protection ratio on the coverage factor was calculated using the same assumptions as stated previously. The results are shown in Fig. 5 and indicate that the coverage factor increases more rapidly with decreasing values of radio-frequency protection ratio when the distance between co-channel transmitters is small. For a distance of 3000 km, for example, the coverage factor is 100 times higher when the radio-frequency protection ratio is 20 dB instead of 40 dB.

4. Conclusions

The main results of the studies mentioned above are reproduced in Fig. 4. Although the studies were purely theoretical and although little is known of propagation beyond 3500 km (which is the major unknown factor in the problem) the relationship between the parameters shown in Fig. 4 exists. There is, especially, no escape from the fact that the number of transmitters that may operate on the same frequency is inversely proportional to the transmitter separation. It is also true that the coverage factor increases with increasing transmitter separation at least for distances below about 5000 km. The accurate values of the coverage factor may, however, be considerably smaller due to either additional interference (e.g. from adjacent channels) or higher field strengths from far distant transmitters or similar effects.

It should be noted that the coverage that can be achieved is least when a ground-wave service is interfered with by sky-wave signals.

There are, however, means by which slight improvements in coverage can be made, e.g. the use of synchronized transmitter networks and, in special cases, the use of directional transmitting antennae. Further studies are necessary on these possibilities as well as on multiple interference and adjacent channel interference effects.

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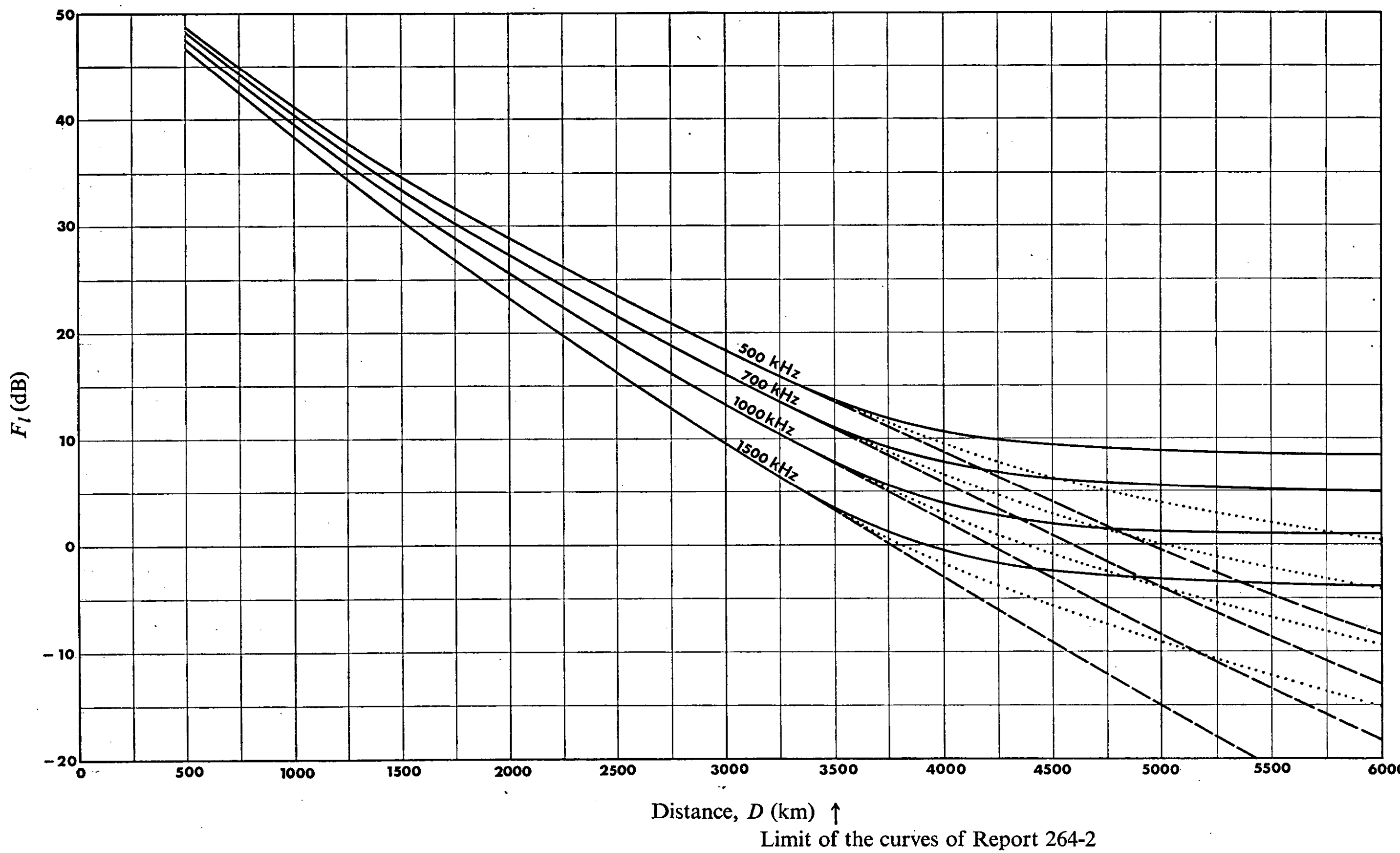


FIGURE 1

Ionospheric propagation curves (Report 264-2)

- - - - - Propagation type No. 1 ——— Propagation type No. 2 .... Propagation type No. 3

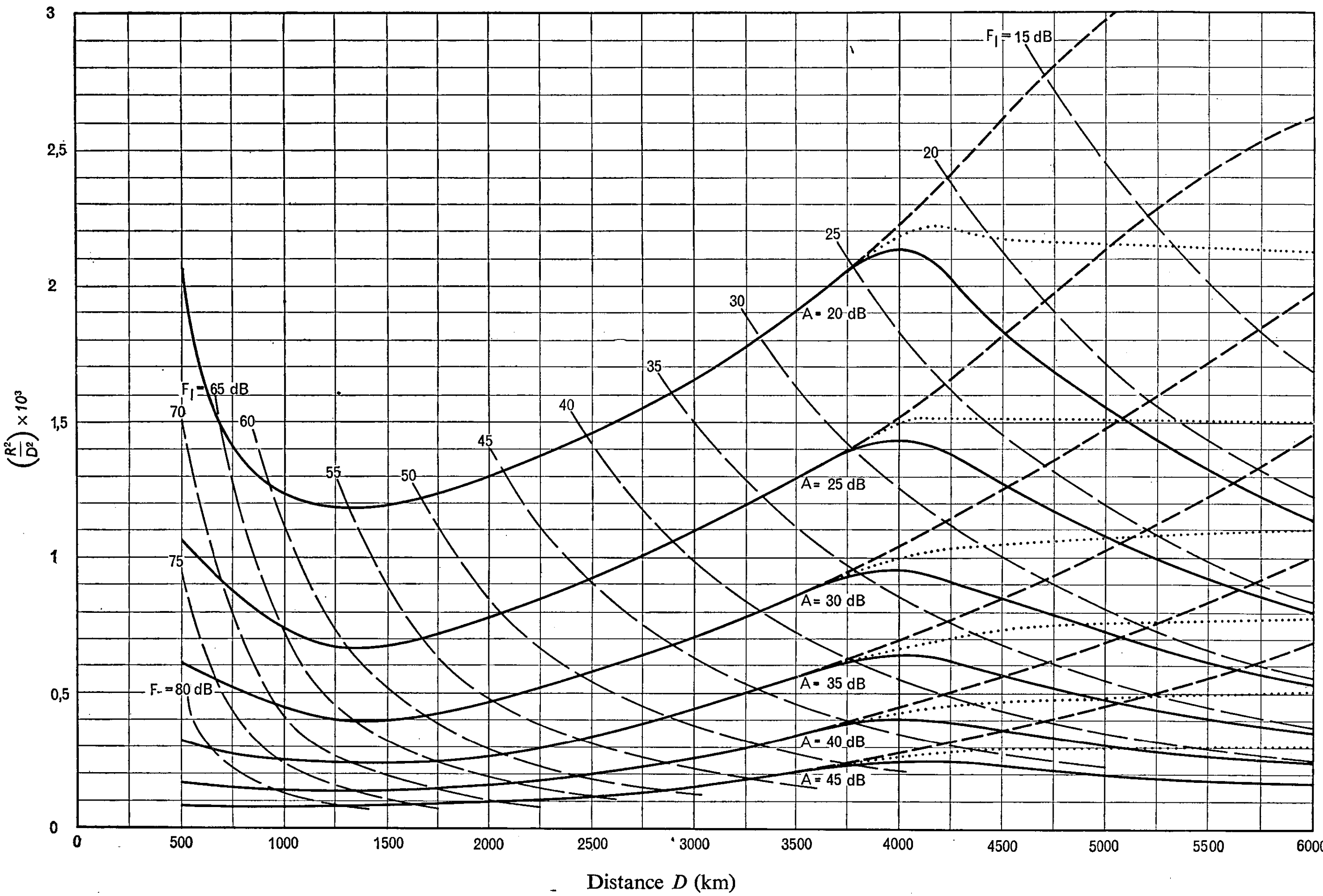
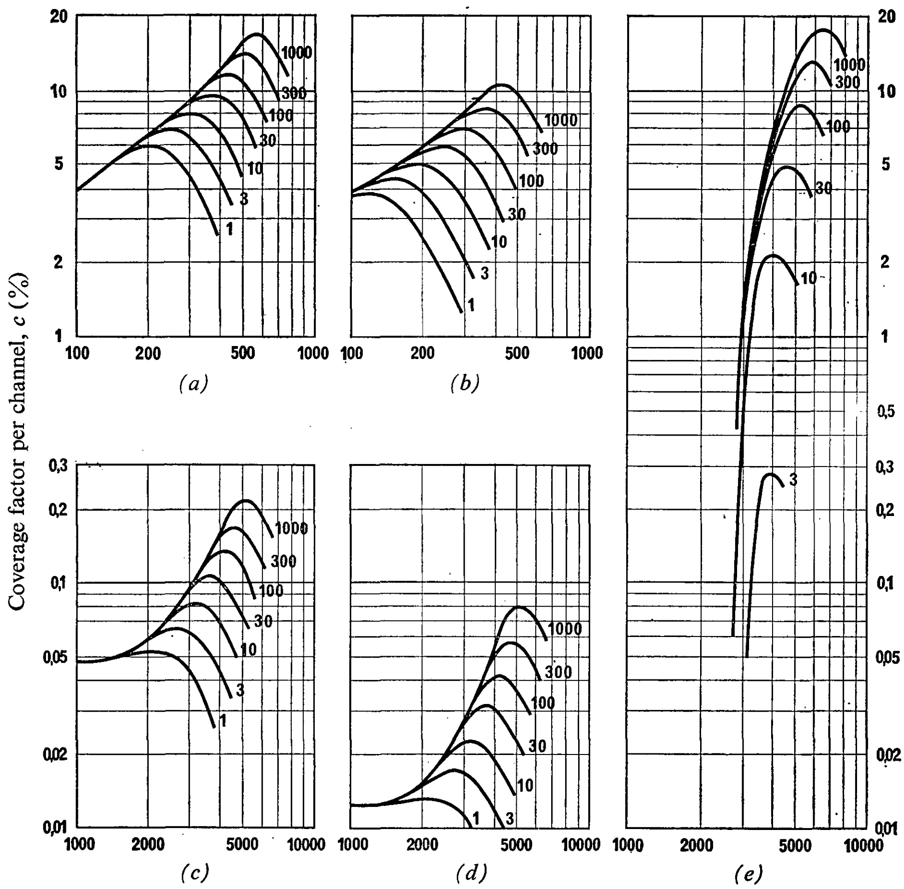


FIGURE 2

Coverage factor

$\sigma = 3 \times 10^{-3}$ mho/m: $f = 1$ MHz



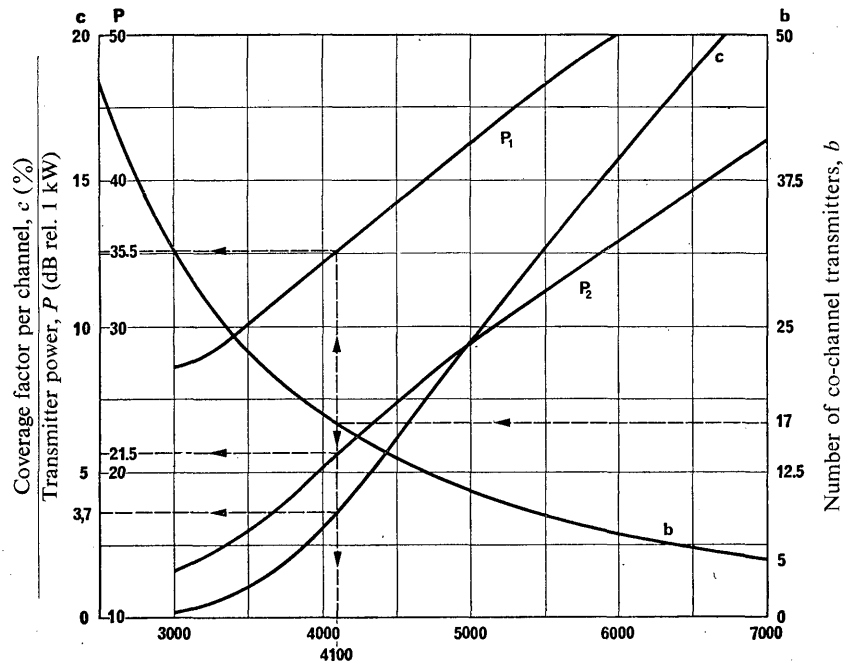
Separation between co-channel transmitters, *D* (km)

FIGURE 3

Coverage factor per channel, c as a function of separation between co-channel transmitters, D for various conditions of propagation

Transmitter power, *P* (kW) is indicated on the curves
Frequency, *f*, 1 MHz
Minimum field strength, F_{min}, 61 dB rel. 1 μV/m
Protection ratio, *A*, 40 dB

Curves	Wanted signal (S_u)	Interfering signal (S_n)	Time
(a)	ground wave (σ = 3)	ground wave (σ = 3)	day
(b)	ground wave (σ = 1)	ground wave (σ = 1)	day
(c)	ground wave (σ = 3)	sky wave	night
(d)	ground wave (σ = 1)	sky wave	night
(e)	sky wave	sky wave	night



Separation between co-channel transmitters, D (km)

FIGURE 4

Number of transmitters, b, transmitter power P and coverage factor per transmitter, c, as functions of the separation between co-channel transmitters, D

Curves P_1: transmitter power (dB rel. 1 kW) for F_{min} = 74 dB rel. 1 μV/m
P_2: transmitter power (dB rel. 1 kW) for F_{min} = 60 dB rel. 1 μV/m
b : number of co-channel transmitters
c : percentage coverage factor per channel

Protection ratio: 40 dB
Frequency f : 1 MHz

Example:

If the number of transmitters sharing the same channel is taken as b = 17, then the co-channel transmitter separation is D = 4100 km, the coverage factor/channel is c = 3·7% and the e.r.p. necessary for all transmitters to make the coverage limiting factor interference rather than noise is:

P = 21·5 dB rel. 1 kW for F_{min} = 60 dB rel. 1 μV/m

or

P = 35·5 dB rel. 1 kW for F_{min} = 74 dB rel. 1 μV/m

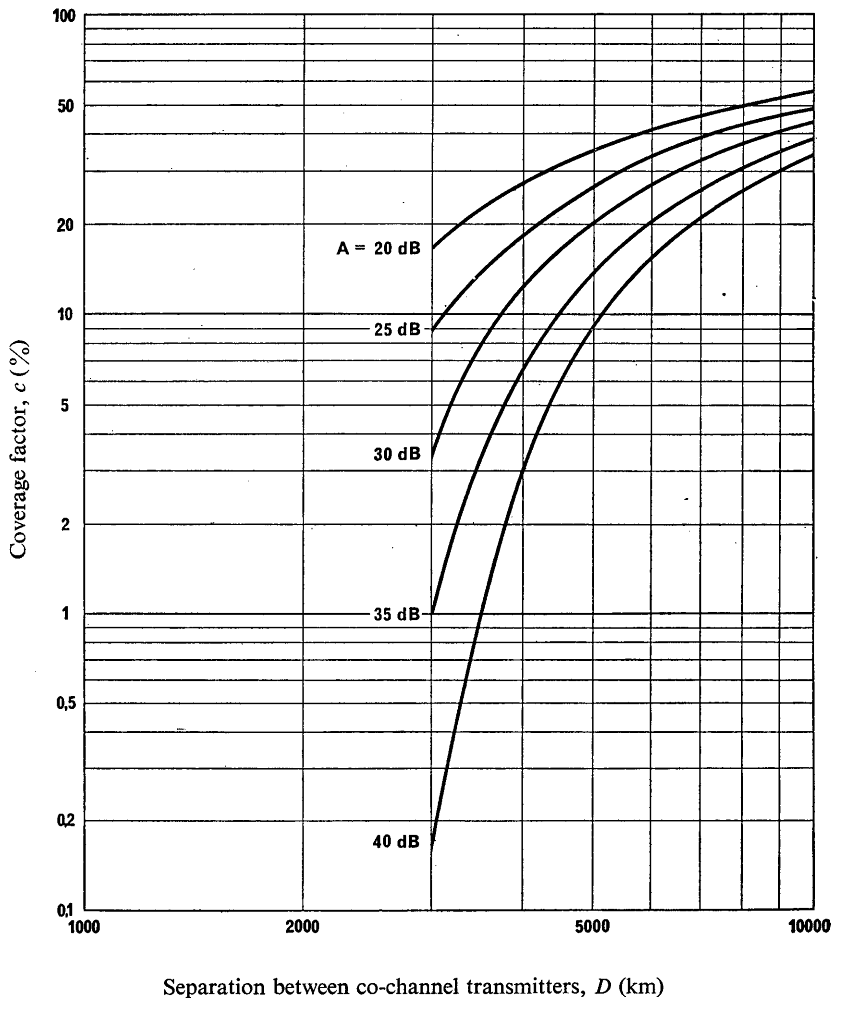


FIGURE 5

Coverage factor for a spherical Earth, c, as a function of separation between transmitters, D, with protection ratio, A as a parameter

Frequency: 1 MHz

REPORT 401-1 *

BROADCASTING IN BANDS 5 (LF) AND 6 (MF)

High-efficiency transmitting antennae

(Question 13/10)

(1966 – 1970)

1. Antenna with reduced vertical radiation

Doc. X/21 (U.S.A.), 1963–1966, describes a high-efficiency anti-fading antenna consisting of a sectionalized tower of two 120° sections (used at the WOAI station at San Antonio, Texas). The " fading zone " area relative to the ground-wave service area is reduced from approximately 50% (for a 0·311 λ antenna) to about 30% for a ground conductivity of 10×10^{-3} mhos/m. The document emphasizes that in this type of antenna the current distribution must be kept as sinusoidal as possible by using a thin structure of uniform cross-section.

Observations. — From experience in other countries it is evident that a high-efficiency anti-fading antenna should be of sectionalized construction and have a total electrical height of $2\lambda/3$ to λ, to produce the necessary rapid rise of sky-wave field strength near to the point where it equals that of the ground-wave. The effect of the resistive component of the antenna current on the vertical radiation pattern of a sectionalized tower can be reduced or compensated by multiple feeding. It should be noted that the location and extent of the " fading zone " varies due to changes in the properties of the reflecting ionospheric layers.

In practice, the fading zone is somewhat larger than that calculated. This might be due on the one hand to variations of the E-layer reflection and on the other hand to F-layer reflections. The design of antennae should take care of these effects.

2. Influence of ground conductivity on the vertical radiation pattern

Doc. X/121 (United Kingdom), 1963–1966, gives the results of a theoretical study into the influence of ground conductivity on the vertical radiation patterns of typical medium frequency antennae. The shapes of these patterns have an important influence on sky-wave reception at great distances and show clearly that at low vertical angles the radiation decreases rapidly as the ground conductivity worsens. Consequently for an efficient sky-wave service the transmitting antennae should be erected on ground of good conductivity. On poor ground the higher angle modes will predominate.

Doc. X/143 (United Kingdom), 1966–1969, gives the results of field-strength measurements carried out to determine the effects of ground conductivity on low angle radiation over a relatively long transmission path of 1400 km. Transmissions from Rome at 845 kHz were measured simultaneously at coastal and inland sites along a radial extending 100 km inland from a coastal site in Southern England. Because of the principle of reciprocity it is immaterial whether the antenna transmits or receives.

Fig. 1 shows the vertical radiation pattern calculated at a frequency of 1 MHz for a short vertical antenna over flat ground of poor conductivity (10^{-3} mhos/m), good conductivity (10^{-2} mhos/m) and sea water (4 mhos/m); fresh water appears to behave like ground of good conductivity. The vertical radiation pattern which would be obtained if the ground were a perfect conductor is also shown for comparison.

* This Report was adopted unanimously.

Fig. 2 shows the results of measurements in terms of field strength at the inland sites, *B* to *K*, relative to the coastal site, *A*. This Figure, therefore, shows how ground loss varies with distance from the sea at the frequency 845 kHz for an angle of arrival of about 4°. Also shown in Fig. 2 are theoretical curves for ground conductivities of 5×10^{-3} mhos/m and 10^{-2} mhos/m which are believed to be the limits for most of the area. Part of the theoretical curve for 2×10^{-2} mhos/m is also included since the first 10 km inland was known to be of about this value. Fig. 2 clearly demonstrates the large ground loss at sites well inland from the coast.

The effective ground loss as a function of the propagation path for single and multi-hop propagation has been calculated and is shown in Fig. 3. E-layer propagation has been assumed.

It is concluded that a transmitter operating in the MF band (band 6) will radiate sky-waves more efficiently at low angles of radiation if it is situated on a coastline facing the area to be served and that the ground loss does not reach its limiting value until the antenna is at least 50 km inland. To obtain maximum advantage open sea must extend from the coastline for a distance of at least 100 wavelengths in the direction of propagation.

Ground loss applies equally to transmitting and receiving antennae.

Doc. X/31 (Italy), 1966–1969, shows the influence of ground conductivity on sky-wave reception.

Field-strength measurements were made over a 450 km transmission path (corresponding to the angle of elevation of about 24°) simultaneously at two points, one on the coast and the other situated inland about 2 km away in the same direction. In the first case, the wave was reflected by the sea and in the second by the ground. Two transmitters in Rome, one operating at 845 kHz and the other at 1331 kHz, were used.

All the data recorded at both receiving points indicate that the median field strength at the coastal site on both frequencies, is 0·5 dB higher than the value measured inland. This result is in agreement with the calculated theoretical value.

3. High-efficiency LF transmitting antenna

3.1 Doc. X/57 (Federal Republic of Germany), 1966–1969, describes a transmitting antenna for use in band 5 (LF), which improves the service area by virtue of its high radiation efficiency. This antenna operates in the band 150 to 160 kHz, has a height of about $\lambda/10$ and a flat frequency response up to at least $\pm$ 6 kHz of the carrier frequency. Its radiation pattern is that of a vertical unipole antenna of the same physical height.

3.2 Doc. X/190 (Sweden), 1966–1969, gives information on experience gained with the broadcasting ring antenna for use in band 5 at Motala (191 kHz). The antenna is a stationary field ring antenna consisting of one central element (a vertical radiator of height 250 m) and five vertical radiators with a height of 200 m, equally spaced on a radius of 630 m (0·4 λ). The total field strengths at distances of up to 300 km from the antenna were recorded at night over a period of several years at several locations both before, and after, the change was made from a short vertical radiator to the ring antenna. The measurements show a substantial extension of the fading-free zone after the change of antenna. The theoretical vertical radiation diagram shows suppression of radiation at angles of 40° to 45° and this has been roughly confirmed by measurements from aircraft.

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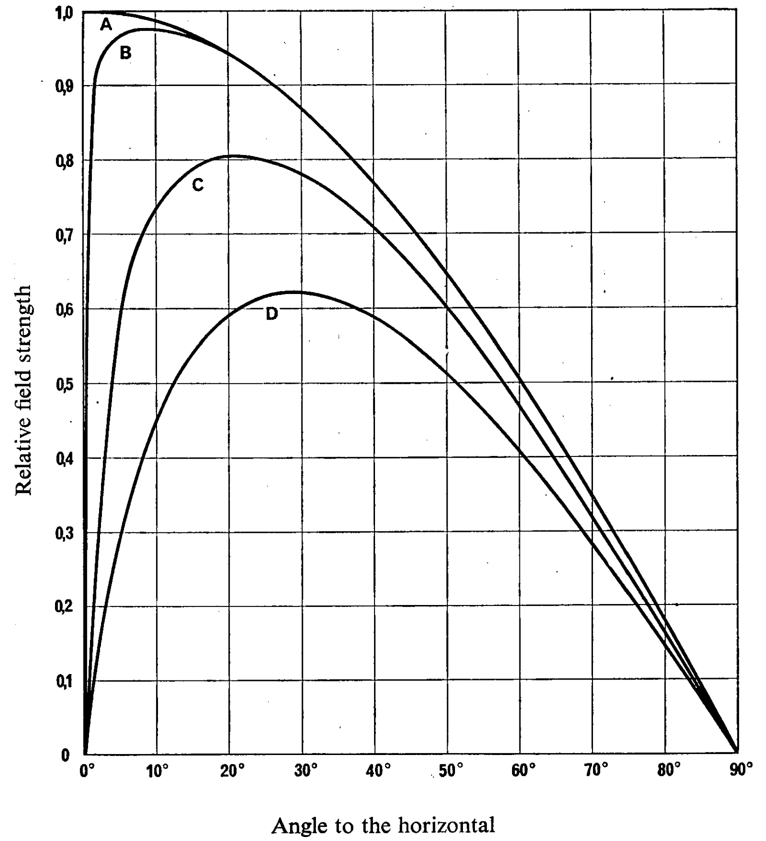

FIGURE 1

Vertical radiation patterns for short vertical antennae at a frequency of 1 MHz

Curve A: perfect conductor
B: sea water (σ = 4·6 mho/m)
C: good ground ($\sigma = 10^{-2}$ mho/m)
D: poor ground ($\sigma = 10^{-3}$ mho/m)

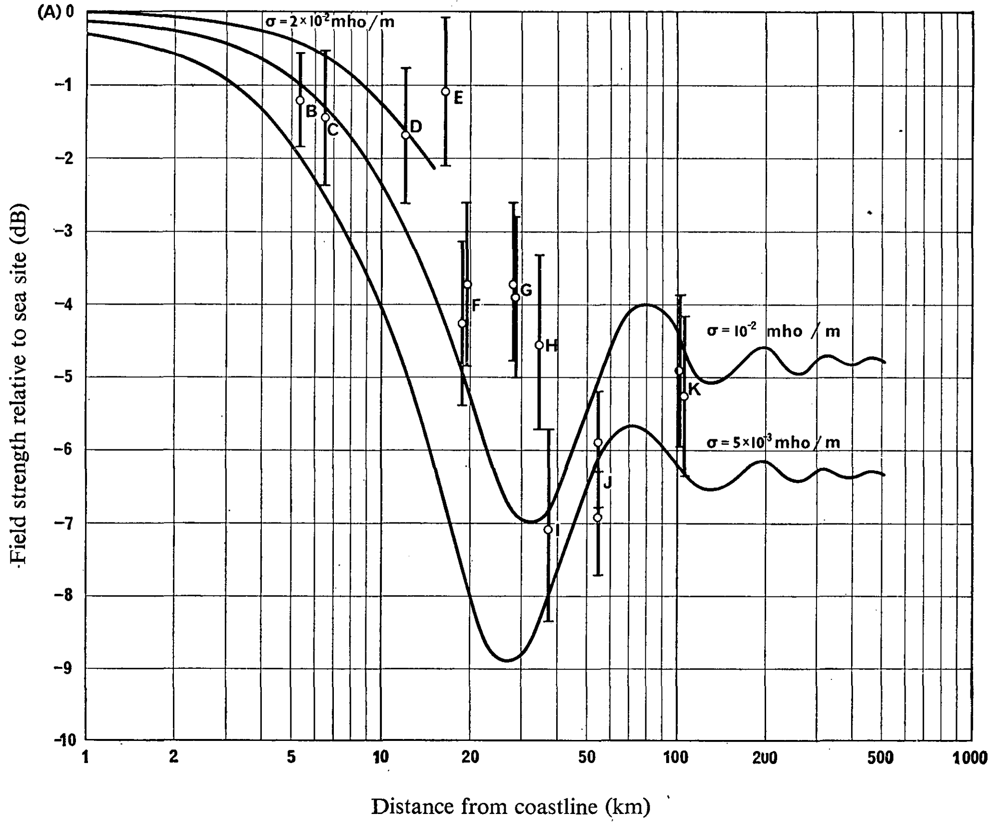

FIGURE 2

Theoretical and measured ground loss

——— : theoretical ground loss
O : measured ground loss

(Vertical lines indicate confidence limits)

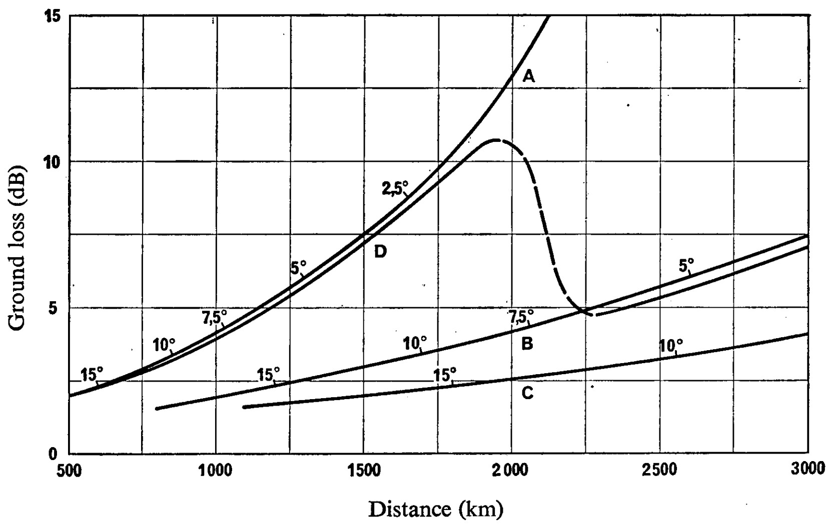

FIGURE 3

Ground loss for multi-hop propagation

The curves show the ground loss which occurs when sea water is replaced by ground of conductivity 5×10^{-3} mho/m at one end of the path. E-layer reflection (layer height 90 km) is assumed and the numbers against the curves denote angles of radiation.

Curve A: single-hop mode
B: two-hop mode
C: three-hop mode
D: effective ground loss for all modes

REPORT 457 *

BROADCASTING IN BANDS 5 (LF) AND 6 (MF) **

Necessary bandwidth of emission

(1970)

1. Introduction

In an amplitude-modulation double-sideband sound broadcasting system the bandwidth of emission is approximately twice the audio-frequency bandwidth of the programme and, therefore, greatly influences the quality of reception. On the other hand, for a given frequency separation between adjacent channels, a limitation of the bandwidth of emission is desirable to avoid mutual interference.

The difference between the transmitted bandwidth for amplitude-modulation sound broadcasting and the receiver bandwidth has led to research [1, 2, 3, 4] aimed at improving the whole transmission system. It appears that it would be useful to fix values for the audio-frequency bandwidth of the programme to be radiated as well as for the overall response of the receivers and to obtain these values by the use of sharp cut-off filters. If both these bandwidths are equal and are suitably related to the channel spacing the transmission system provides for the full utilization of the transmitted bandwidth as well as for the most favourable protection against adjacent channel interference [5].

2. Assessment of the necessary bandwidth of emission

Obviously the bandwidth of emission as well as the passband of the receivers should be chosen in such a way that there is no unnecessary impairment of reception quality or any increase in adjacent channel interference [2]. In this respect a good solution would be to make the channel spacing, the bandwidth of emission and the receiver passband of equal value. Moreover, ideally there should be rectangular limitation of the bandwidth of emission and the received selectivity curve and no non-linear distortion in the transmitter. Under these conditions no adjacent channel interference would occur.

In practice, however, none of these requirements is met. In particular, the bandwidth of emission usually exceeds the channel spacing by a considerable amount and, in consequence, this has led to the manufacture of domestic receivers with reduced bandwidths which degrades the quality of sound reproduction. Moreover, adjacent channel rejection is not improved. However, relatively low values of adjacent channel radio-frequency protection ratios can be tolerated when using transmitters with low values of distortion ($\leqslant 1\%$) and receivers with filters (e.g. mechanical types) having steep slopes and passbands that are of the same order as the channel spacing.

3. General considerations

3.1 The relationships between the four parameters of radio-frequency protection ratio, channel spacing, audio-frequency bandwidth of the programme and overall response of the receivers need clarification. As a first step investigations may be restricted to the case where the audio-frequency bandwidths are equal for both transmission and reception thereby reducing the number of parameters to be considered to three.

* This Report was adopted unanimously.

** Report 297-2 deals with the corresponding problems for broadcasting in band 7 (HF).

3.2 The theoretically obtainable optimum value of protection against adjacent channel interference can be assessed by using an ideal receiver with rectangular passband characteristics. In this case the radio-frequency protection ratio is mainly determined by non-linear distortion in the transmitter.

3.3 A theoretical study of the energy spectrum including out-of-band radiation caused by transmitter non-linearities is contained in [6]. Experimental investigations of the energy spectrum of a high-power transmitter operating in band 6 (MF) [7] show that the term occupied bandwidth as defined in [8] does not give an adequate indication of the effects of bandwidth limitation on adjacent channel interference.

4. Measurement results

4.1 Measurements of the radio-frequency protection ratios for the case of various values of audio-frequency bandwidths, which are equal at both transmitter and receiver, and at different channel spacings have been carried out in the Federal Republic of Germany [4] using the objective two-signal measuring method [9]. For the measurements a high quality commercial receiver with an almost ideal passband characteristic was used. The interrelation between the parameters involved are shown in Fig. 1. For a given channel spacing there are many pairs of values of audio-frequency bandwidths and adjacent channel protection ratios. If, however, two of the parameters have been chosen, the third is definitely fixed.

4.2 Subjective listening tests were made in the United States of America and in the United Kingdom [1, 3] whereas in the Federal Republic of Germany radio-frequency wanted-to-interfering signal ratio measurements [2] were made according to the objective two-signal method of measurement [9]. In both cases the radiated bandwidth was restricted by means of a low-pass filter at the audio-frequency input to the transmitter.

In the United States of America two table models, one pocket transistor set and one automobile transistor set were used. In the United Kingdom four transistor portables and one valve table model were taken. In the Federal Republic of Germany the receivers used were E.B.U. reference receivers MEK and MBF [10], five domestic receivers currently manufactured in the Federal Republic of Germany and two special receivers equipped with mechanical intermediate-frequency filters.

In the three countries no noticeable degradation of the reception quality was observed with current types of receiver when the bandwidth of emission was limited by a low-pass filter, having a cut-off frequency of about half the adjacent channel carrier frequency separation, inserted at the input to the transmitter.

Mean values of improvement in adjacent channel rejection with current types of receiver resulting from the limitation of the bandwidth of emission, are given in Table I. Values obtained in the Federal Republic of Germany with a special receiver equipped with mechanical filters are shown in parenthesis.

In the subjective listening tests carried out in the United States of America the absolute values of adjacent ratio vary considerably with the type of programme, nevertheless, the mean values of improvement correspond fairly well to the values obtained by the objective method of measurement used in the Federal Republic of Germany.

TABLE I

Improvement in adjacent channel rejection

Ratio of audio-frequency bandwidth to channel spacing	Channel spacing Δf (kHz)	Cut-off frequency of low-pass filter (kHz)	Subjective tests (*S*) or objective measurements (*O*)	Mean value of improvement in adjacent channel rejection (dB)
0·45	10	4·5	*O* (FRG)	12 (29)
0·5	9	4·5	*O* (FRG)	5 (20)
0·5	9	4·5	*S* (UK)	3·6
0·525	10	5·25	*S* (USA)	3 (¹)
0·5625	8	4·5	*O* (FRG)	2 (7)
0·5625	8	4·5	*S* (UK)	0·9
0·643	7	4·5	*S* (UK)	0·3
0·7	7·5	5·25	*S* (USA)	negligible

(¹) This figure represents the difference between the extreme limits of the " just perceptible " radio-frequency wanted-to-interfering signal ratios obtained with and without filter (see [1]).

5. Radio-frequency and intermediate-frequency passband characteristics of current types of receiver

Receiver characteristics have been collated in various countries and are partly reproduced in [11]. Radio-frequency and intermediate-frequency passband values between the 6 dB points are quoted ranging between 5 and 10 kHz. It should be noted that the reproduced audio-frequency bands are about half these values. The highest values mentioned are those of " first category " receivers in the U.S.S.R. [12] with variable selectivity.

It is known that there are many receivers with even smaller passbands than those mentioned in the above references.

6. Use of bandwidth limitation in operational practice

On an experimental basis a growing number of transmitters are now operating in bands 5 (LF) and 6 (MF) with a limited bandwidth. One or more high-power transmitters are operated in this manner in the following countries: Austria, Finland, Federal Republic of Germany, Luxembourg, Monaco, the Netherlands, Sweden and the United Kingdom [13].

This development started in 1966 and public reaction to the effect on programme quality has been negligible. On the other hand, improved reception has been reported in several cases where adjacent channel interference had previously been severe.

7. Conclusions

7.1 Fig. 1 shows the relationship between the adjacent channel radio-frequency protection ratio, the channel spacing and the audio-frequency bandwidth and assumes that the audio-frequency bandwidth of the radiated programme is the same as that reproduced by the receiver. When two of the three parameters are selected, the third is definitely fixed. In general the channel spacing will be given and a particular value of radio-frequency protection ratio will be required. Then the full audio-frequency bandwidth as taken from Fig. 1 can be transmitted but full use of the bandwidth of the radiated signal can only be made if the receivers have selectivity characteristics corresponding to that of the audio-frequency filter at the transmitter.

7.2 Measurements made in the United Kingdom, the United States of America and the Federal Republic of Germany show that a reduction of adjacent channel interference can be obtained, if the bandwidth of emission is made approximately equal to the channel spacing. Neither in laboratory tests nor in practice has the restriction of the bandwidth of emission led to any noticeable deterioration in reception quality when using current types of domestic receiver. Thus, bandwidth limitation techniques could lead to a more efficient use of bands 5 (LF), 6 (MF) and 7 (HF) for broadcasting.

7.3 It is desirable that further studies should be carried out in other countries, including, in particular, the use of receivers having intermediate-frequency filters with steep slopes.

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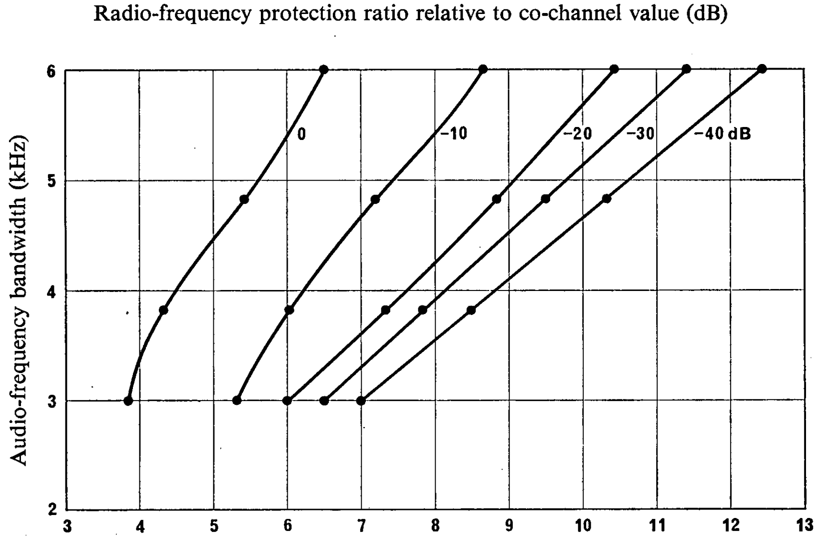

FIGURE 1

Use of the frequency spectrum

REPORT 458 *

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

(Question 25/10)

(1970)

1. Introduction

Question 25/10 relates to the possibility of standardizing one or more sound broadcasting systems on a worldwide basis. It is clear that the study of this complex question is not sufficiently advanced to achieve this aim. The present Report, therefore, is only a summary of the information available, intended to encourage Administrations, broadcasting organizations and industry to take an interest in these questions and to undertake the studies necessary to solve them.

At present, broadcasts in bands 5, 6 and 7, unlike sound and television broadcasting in band 8 (VHF), are operated throughout the world with an almost complete absence of internationally standardized transmission characteristics, with the exception of channel spacings and carrier frequencies for bands 5 and 6, but even these differ from Region to Region. The other transmission characteristics vary from country to country and in many cases even from transmitter to transmitter [1].

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* This Report was adopted unanimously.

2. Systems available for standardization

The following list of possible systems cannot, at the present time, be considered as complete. Several of these systems are compared in [2]. This study also shows that interference between transmitters must be considered when defining a system and the importance of well-defined channel spacings becomes apparent.

Modulation	Detection	Code
Amplitude-modulation, double sideband	Envelope detection	AM-DSB-ENV
Amplitude-modulation, double sideband	Synchronous detection	AM-DSB-SYNC
Compatible single sideband amplitude-modulation	Envelope detection	CSSB
Single sideband amplitude-modulation	Synchronous detection	SSB-SYNC
Frequency modulation (narrow band)		FM

Each of the above systems may incorporate modulation processing devices (see Note). If such a device is necessary in the receiver to obtain full advantage of a similar device in the transmitter, the code should be completed by a suitable abbreviation. Thus, an amplitude-modulation double-sideband system with envelope demodulation comprising a compressor in the transmitter and an expander in the receiver, is coded AM-DSB-ENV-COMPANDOR. An example is given in Annex I.

Note. — By " modulation processing " is understood any process consisting in altering certain characteristics of the modulation, such as the dynamic range, audio-frequency bandwidth, etc.

Descriptions of amplitude-modulation double-sideband systems with synchronous detection appear in [3] and [4] and it should be noted that only these systems can serve as transition systems from amplitude-modulation double-sideband systems with envelope detection to single-sideband systems with synchronous detection. Receivers based on synchronous detection would produce undistorted audio-frequency signals for both the above systems (" receiver compatibility ").

3. Characteristics to be specified

For the systems mentioned in § 2, the characteristics whose standardization will be required are given below. This list is not necessarily complete.

3.1 *All systems*

— audio-frequency bandwidth of the programme,

— necessary bandwidth of emission,

— channel spacing,

— overall bandwidth of the receiver.

Note 1. — For the relationship between these characteristics, see Report 457.

— carrier frequencies,

— intermediate frequency or frequencies,

— receiver oscillator frequency stability.

Note 2. — The relationship between these characteristics is shown in Annex II.

— characteristics of modulation processing devices.
In addition, the following characteristics should be standardized:

3.2 *Amplitude-modulation double-sideband and compatible single-sideband systems*

— maximum depth of modulation.

3.3 *Compatible single-sideband systems and single-sideband systems with synchronous detection*

— degree of suppression of the unwanted sideband,

— maximum permissible values of intermodulation products.

3.4 *Single-sideband systems with synchronous detection*

— degree of suppression of the carrier wave,

— auxiliary signals to obtain receiver synchronization.

3.5 *Frequency modulation*

— modulation index,

— maximum modulation frequency.

4. Transition period

The consequences of a change from a situation without standards to the final implementation of a system can only be forecast with precision when the numerical values of the characteristics shown in the preceding section are known.

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ANNEX I

THE USE OF AUDIO-FREQUENCY COMPRESSION AND EXPANSION

A preliminary study has been carried out in Sweden concerning the improvement in radio-frequency wanted-to-interfering signal ratio obtained by using audio-frequency compression and expansion in connection with a double-sideband amplitude-modulation system and a frequency modulation system with a maximum deviation of ± 5 kHz.

The audio-frequency range was from 40 to 5000 Hz.

The compressor had a transfer ratio 2/1 (in dB), the time-constants were 2 ms for the rise-time and 20 ms for the decay-time. The expander had characteristics reciprocal to those of the compressor.

The test results can be summarized as follows:

In the absence of interference, no change in quality was observed when using both compressor and expander in the system. The quality was also judged to be satisfactory by listening when only the compressor was used.

In the presence of co-channel interference, the radio-frequency protection ratios (dB) were found to be as follows:

	Type of modulation	
	Amplitude	Frequency
— without compressor and expander	40-50	40-45
— with compressor only	30-40	30-40
— with compressor and expander	20-25	25-30

It should be noted that these values were obtained for an interfering transmitter not equipped with a compressor.

ANNEX II

CHANNEL SPACING, PROTECTION RATIO AND INTERMEDIATE FREQUENCY

When choosing the carrier frequencies, channel spacing and also the intermediate frequencies to be used in receivers, it is important that they should be chosen to minimize interference from

— the local oscillators of the receivers in use or of nearby receivers, either by the fundamental or a harmonic frequency;

— harmonics of a transmitted frequency, or other possible intermodulation products [1, 2].

If both the carrier frequencies and the intermediate frequency are an integral multiple of the carrier spacing, then all interfering products will also be integral multiples of the carrier spacing. Theoretically, therefore, maximum protection could then be obtained because the frequency difference between any interfering signal of this kind and the wanted carrier frequency would be zero or a multiple of the channel spacing.

If these requirements are to be met in a particular broadcasting band it would be essential for the channel spacing to be uniform throughout the band. It would be more advantageous, moreover, if this condition could be met in both bands 5 and 6 or better still throughout bands 5, 6 and 7. On the other hand, this condition should be satisfied on a world-wide scale or at least in those areas, where a single frequency assignment plan exists or will be established [3].

However, it must be noted that the disturbance caused by an interfering signal increases rapidly as its frequency difference from the wanted signal increases from zero.

Under present-day conditions the frequency differences might have any possible value and this may require an additional protection ratio of up to 20 dB. With the adoption of the proposed arrangement, the maximum frequency difference would depend on the accuracy with which the local oscillator frequency and the centre frequency of intermediate-frequency passband can be controlled. In order to achieve an improvement close to the maximum possible it would be necessary to achieve stabilities of the order of 100 Hz. As far as the intermediate-frequency stability is concerned this could be achieved by using ceramic or mechanical filters rather than using conventional intermediate-frequency coils. The control of the initial tuning operation and the frequency drift of the local oscillator may require special techniques in which automatic frequency control may be required. The adoption of the proposal would, therefore, give little improvement in the short term, with existing receivers, but would offer the chance of substantial improvement in the future without any disadvantages under present-day conditions.

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REPORT 459 *

RADIO-FREQUENCY PROTECTION RATIO FOR SYNCHRONIZED BROADCASTING TRANSMITTERS

(Study Programme 25A/10)

(1970)

Investigations have been carried out in the U.S.S.R. (Doc. X/213, 1966–1969) to determine values of signal-to-interference ratio applicable to reception of transmissions from synchronized transmitter groups comprising two or three transmitters. Both phase and frequency methods of synchronization were considered.

1. Protection ratio

The term protection ratio means the ratio of the field strength of the strongest signal from one of the transmitters in the synchronized group to the resultant field strength of the remaining transmitters in the same group.

2. Determination of acceptable protection ratio

For the purpose of determining the protection ratio, use was made of a statistical method based on subjective impressions of reception quality from a transmitter in a synchronized group compared with reception quality of a single non-synchronized transmitter station. Twenty-six experts were employed—all of whom were technical and scientific broadcasting staff.

Protection ratio values for non-fading signals were determined under laboratory conditions and later verified under operational conditions.

For fading signals only operational tests using a synchronized network were carried out.

For all these tests the depth of maximum modulation was 90%.

3. Results of investigations

Fig. 1 shows the variations in protection ratio as a function of the phase shift between the carriers of two stations during daytime in the absence of fading. The parameter used in these curves is the percentage of experts who rated the total signal as being at least satisfactory.

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* This Report was adopted unanimously.

It will be seen from this figure that, to satisfy 90% of the listeners, the protection ratio for a network consisting of two synchronized stations for reception without fading was 4 dB.

Fig. 2 shows the variation in protection ratio as a function of the difference in frequency between two synchronized transmitters for the percentage of experts who found the reception quality of the total signal from the synchronized transmitters to be satisfactory. This figure shows that, for non-fading signals with two synchronized transmitters and a protection ratio of 4 dB, it is necessary to have a synchronization accurate to 0·015 to 0·02 Hz, to satisfy 90% of listeners. With a mistuning of 0·1 Hz the protection ratio has to be increased to 6 dB.

Fig. 3 contains similar curves for phase synchronization operation of three transmitters. To satisfy 90% of the listeners the protection ratio should not be less than 3·1 dB. (The standard used is 4 dB.)

It is concluded that when reception is affected by fading it will be necessary to increase the protection ratio to 7 to 8 dB in the case of two synchronized transmitters, and to 6 dB in the case of three transmitters.

Note. — Measurements carried out in other countries, notably, Austria, France, Federal Republic of Germany, Italy, Netherlands, Norway, Sweden, United Kingdom, Australia and the United States of America, are given in [2] which contains an extensive bibliography.

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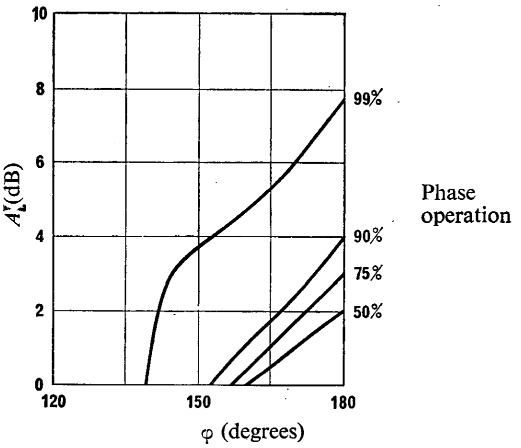

FIGURE 1

Quality of speech and music transmissions as a function of the phase difference between the carriers of two stations (non-fading conditions)

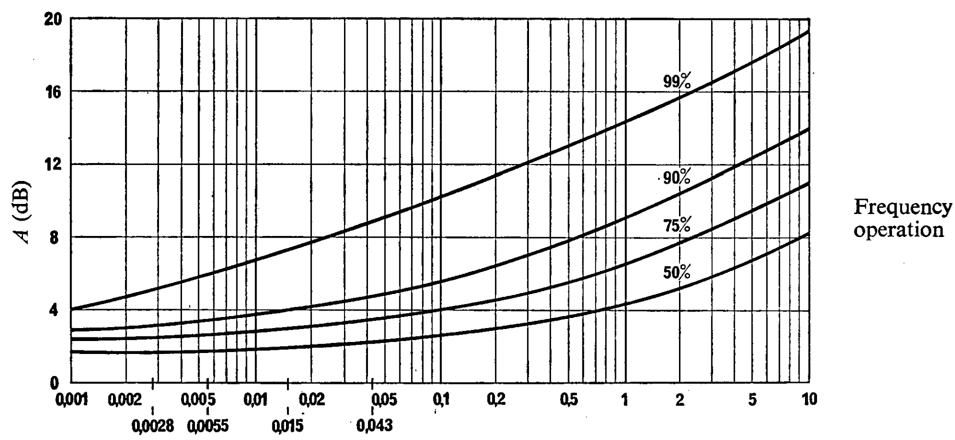

FIGURE 2

Quality of speech and music transmissions as a function of carrier synchronization accuracy of two stations (non-fading conditions)

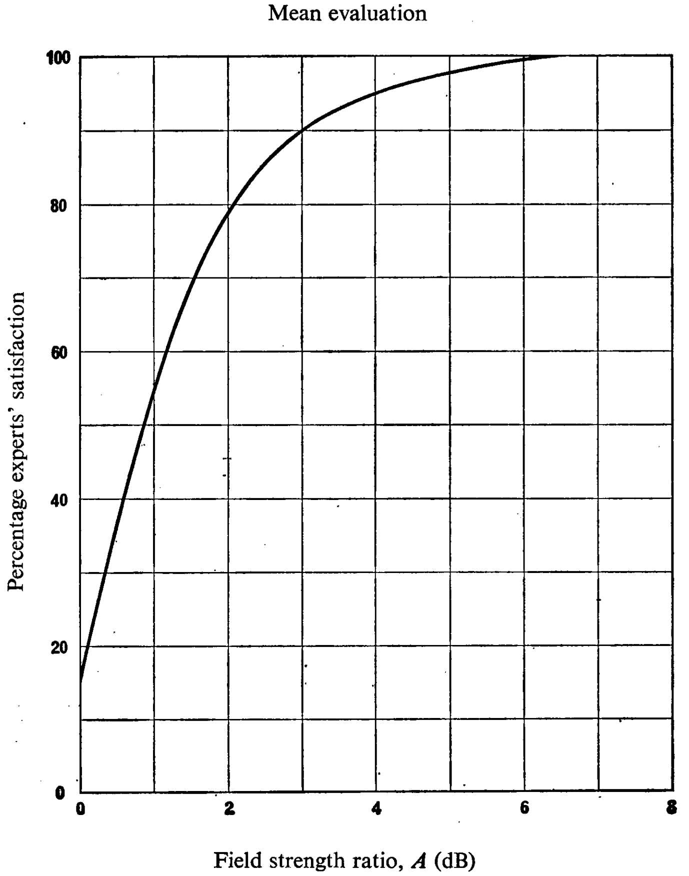

FIGURE 3

Quality of speech and music transmissions as a function of carrier synchronization accuracy of three stations (non-fading conditions)

REPORT 460 *

IONOSPHERIC CROSS-MODULATION

(Study Programme 25E/10)

(1970)

The effects of ionospheric cross-modulation in bands 5 (LF) and 6 (MF) are becoming a problem of increasing severity as the power of transmitters continues to increase.

* This Report was adopted unanimously.

1. Detailed experiments on this subject have been carried out in several countries, notably, in the United Kingdom and in the Federal Republic of Germany [19, 20]. These experiments were carried out with conventional amplitude-modulation double-sideband transmissions. It is not yet possible to give the exact and final values of the interference observed, but the following results may be deduced from these experiments:

1.1 The percentage of cross-modulation increases practically linearly with the power of the interfering transmitter and also increases with the depth of modulation.

Note. — The percentage cross-modulation is the percentage by which the carrier of the wanted transmitter is modulated by the modulating frequencies of the interfering transmitter.

1.2 The cross-modulation depends primarily on the power radiated by the interfering transmitter in the direction of the reflection point of the wanted signal in the ionosphere.

1.3 The percentage of cross-modulation increases as the modulating frequency of the interfering transmitter is decreased.

2. Very large percentages of cross-modulation were observed during measurements carried out between 1935 and 1956.

3. Fig. 1 shows the percentages of cross-modulation measured in all experiments normalized for an interfering transmitter e.r.p. of 500 kW modulated at a frequency of 400 Hz using an extrapolation law based on the theory postulated in [21]:

— in band 5 (LF), the percentages of cross-modulation are shown to be of the order of 10% for the carrier frequencies quoted;

— in band 6 (MF), the values of cross-modulation are slightly lower, except near the gyro-magnetic frequency, where very large percentages have been observed in certain cases. However, it is thought that the extreme values correspond to periods of very severe fading of the wanted signal.

4. The effects of cross-modulation should be taken into account not only for sky-wave reception, but also for ground-wave reception at the edge of the service area when at night the sky-wave is no longer negligible. However, the effect of cross-modulation is reduced approximately in the ratio of the wanted signal levels, ground-wave to sky-wave, at the receiving point.

5. In view of the important differences in the results indicated in Fig. 1, further studies are necessary to determine the maximum permissible radiated power of transmitters operating in bands 5 and 6; such limits are essential to avoid disturbing effects in the service area of other transmitters.

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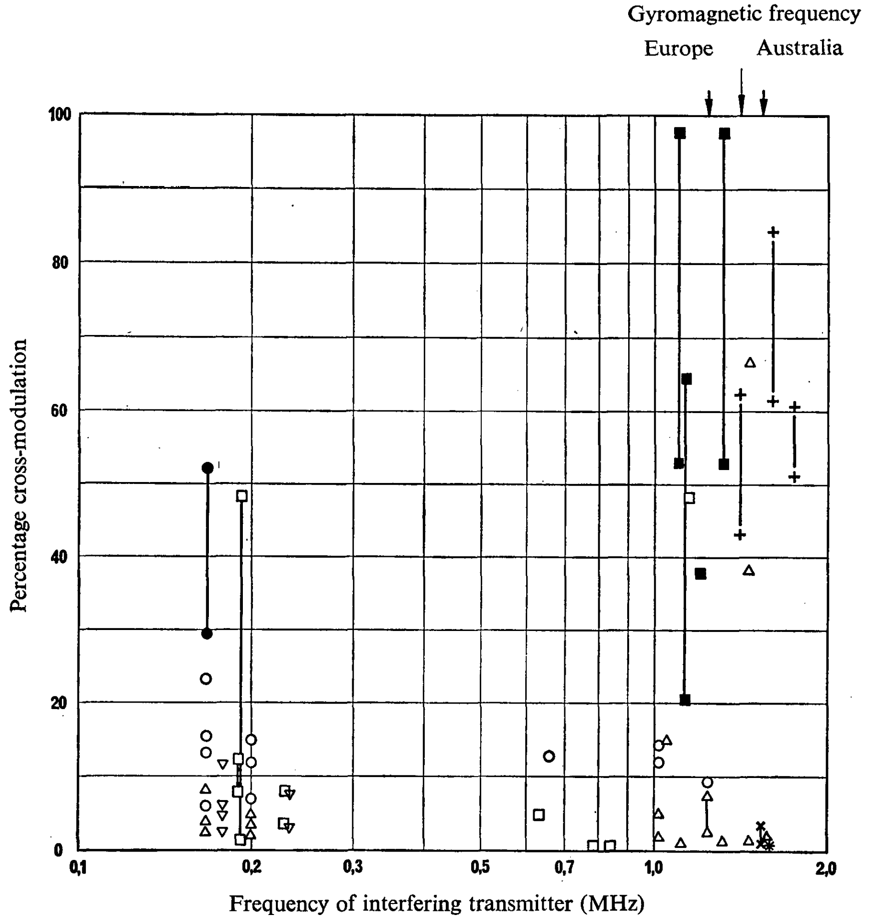

FIGURE 1

Ionospheric cross-modulation at medium latitudes

The ordinate represents the modulation induced when the percentage modulation of the interfering transmitter is 70 to 80%. The values are normalized for an interfering transmitter e.r.p. of 500 kW and a modulation frequency of 400 Hz.

□ pre-war	[1, 2, 3, 4]
○ Cambridge	[6, 12, 14]
● København	[12]
△ Birmingham	[5, 7, 10, 13, 16]
■ Italy	[8, 9, 11, 17]
+ Australia	[15, 18]
▽ Luxembourg and Europe I	[19, 20]
× B.B.C. measurements (1968)	
✱ Measurements by the FTZ, Darmstadt (1968)	

Individual points indicate average values; points joined with vertical lines indicate a range of measured values.

REPORT 461 *

BROADCASTING IN BAND 6 (MF)

Reduction of sky-wave field strength

(Question 11-1/10)

(1970)

1. Introduction

Studies have been carried out in Australia to investigate a method of sky-wave field-strength reduction which exploits the high absorption of extraordinary waves for transmission frequencies near the gyrofrequency. The transmitting antenna for this system is required to radiate a signal polarized in such a manner that waves entering the ionosphere do so exclusively through extraordinary modes. The system is termed orthogonal transmission.

2. Experimental tests

Doc. X/133 (Australia), 1966–1969, describes propagation tests conducted in 1965 and 1967 which indicate that the median value of the sky-wave field strength from a broadcasting transmitter operating in band 6 (MF) may be reduced by 16 dB on paths to the north in the southern hemisphere, when conventional vertically polarized transmission is replaced by orthogonal transmission. No significant change in this reduction was evident on south-north paths extending from 243 km to 695 km. The reduction decreased on paths with eastward or westward components due to features in the design of the transmitting antenna, which did not provide the polarization ellipse tilt required on such paths. A field-strength reduction of 13 dB was measured on paths which were 19° to the east or west of the bearing of the target area (magnetic North).

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REPORT 516 *

FIELD STRENGTH RESULTING FROM TWO OR THREE STABLE ELECTROMAGNETIC FIELDS

(1970)

Doc. X/56 (Italy), 1966–1969, discusses the composition of several fields at one and the same point.

1. Field strength resulting from two stable electromagnetic fields

If two fields of different frequencies are considered at a point in space:

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* This Report was adopted unanimously.

$$E_1 = A \cos \omega t$$
$$E_2 = B \cos [(\omega + \Delta\omega)\, t + \varphi]$$

where A, B, ω, $\Delta\,\omega$ and φ are constant in time, and if it is assumed that both fields are polarized in the same direction, the instantaneous amplitude of the vector representing the resultant field is:

$$E = \sqrt{A^2 + B^2 + 2\,AB \cos (\Delta\omega t + \varphi)}$$

The mean value of E in the period $T = 2\,\pi/\Delta\omega$ is:

$$E_R = (1/T) \int_{t_0}^{(t_0 + T)} E\,(t)\,\mathrm{d}t = Af\,(A/B)$$

If the values A, B and E_R (dB rel. 1 μV/m) are designated by F_1, F_2 and $(F_1 + \Delta_R)$ respectively and assuming that $F_1 \geqslant F_2$, a graph can be drawn of the value of Δ_R as a function of $(F_1 - F_2)$ and the curve (continuous line) shown in Fig. 1 is obtained.

The dotted line shown in Fig. 1 is obtained by calculating the r.m.s. of the amplitudes of the two fields

$$E_R = \sqrt{A^2 + B^2}.$$

The values of the first curve are always lower than those of the second curve, for each value of $(F_1 - F_2)$. The maximum difference is 0·8 dB for $F_1 = F_2$.

2. Field resulting from three stable fields

Let:

$$E_1 = A \cos \omega t$$
$$E_2 = B \cos [(\omega + \Delta\omega_1)t + \varphi_1]$$
$$E_3 = C \cos [(\omega + \Delta\omega_2)t + \varphi_2]$$

be three fields (with the same assumption as before).

If the values A, B, C and the mean instantaneous amplitude of the vector representing the resultant (dB rel. 1 μV/m) are designated by F_1, F_2, F_3 and $(F_1 + \Delta_R)$ respectively, and assuming that $F_1 \geqslant F_2$, $F_1 \geqslant F_3$, a graph can be drawn in which the curves give the values of Δ_R as a function of $(F_1 - F_2)$ and $(F_1 - F_3)$.

The results obtained are shown in Fig. 2. It can be seen, for example, that when $F_1 = 63$ dB, $F_2 = 61$ dB and $F_3 = 60$ dB, then $\Delta_R = 2{\cdot}6$ dB.

3. Experimental results

Measurements of field strength carried out at the RAI monitoring centre at Monza have led to the following deductions:

- considering two or three amplitude-modulation emissions in band 6 (MF) on the same channel,
- assuming a difference of at least a few hertz between the carrier frequencies, and
- assuming that the signals at the reception point are stable,

it may be taken that the measured value of the resultant field is, with an approximation of 0·2 dB, that which is deduced from the continuous lines in Figs. 1 and 2 respectively.

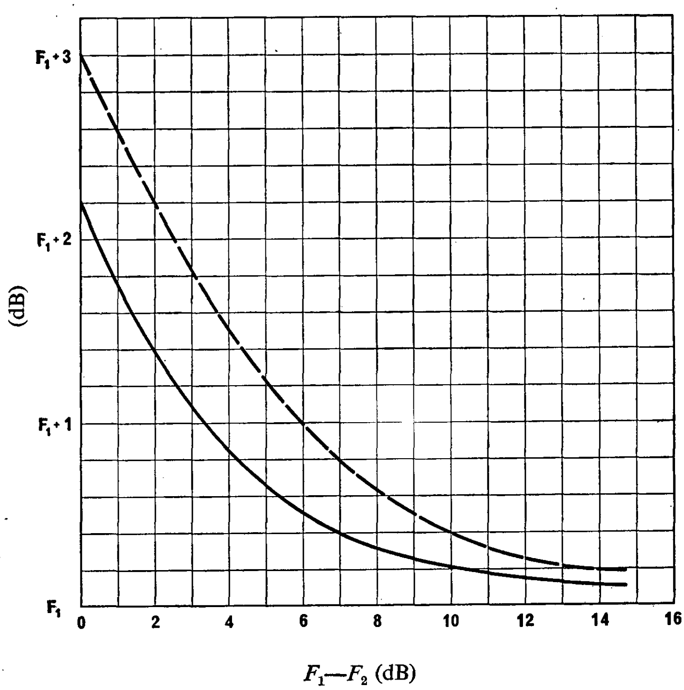

FIGURE 1

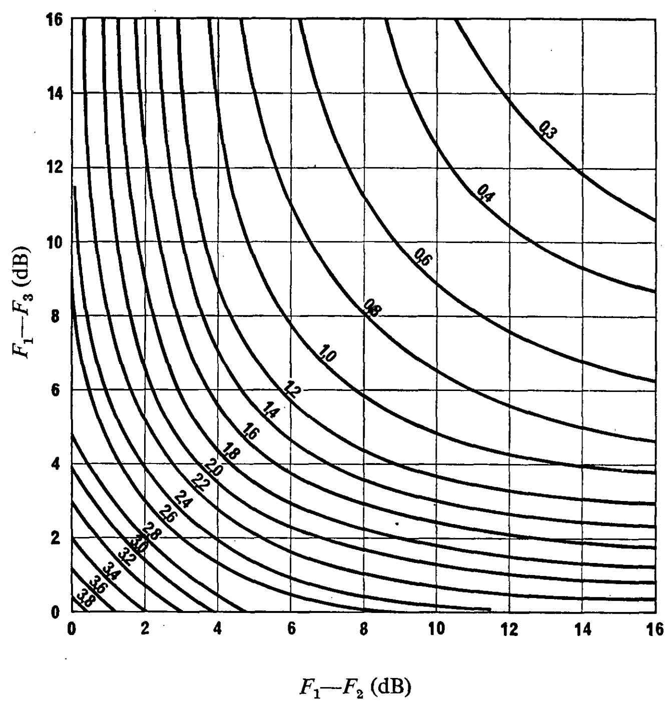
0,3
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
2,2
2,4
2,6
2,8
3,0
3,2
3,4
3,6
3,8
$F_1—F_3$ (dB)
$F_1—F_2$ (dB)

FIGURE 2

SECTION 10B: FREQUENCY-MODULATION SOUND BROADCASTING IN BANDS 8 (VHF) AND 9 (UHF)

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 412

STANDARDS FOR FREQUENCY-MODULATION SOUND BROADCASTING IN BAND 8 (VHF)

The C.C.I.R. (1956 – 1959 – 1963)

UNANIMOUSLY RECOMMENDS

that for frequency-modulation sound broadcasting in band 8 (VHF);

1. the maximum frequency deviation should be either ± 75 kHz or ± 50 kHz;

2. the pre-emphasis characteristic should be defined as a curve rising with frequency in conformity with the admittance of a parallel combination of a capacitance and a resistance having a time constant of either 50 or 75 μs;

3. in the absence of interference from industrial and domestic equipment, a field strength (measured 10 m above ground level) of at least 50 μV/m can be considered to give an acceptable service;

4. in the presence of interference from industrial and domestic equipment, a satisfactory service requires a median field strength (measured 10 m above ground level) of at least:
   - 0·25 mV/m in rural areas,
   - 1 mV/m in urban areas,
   - 3 mV/m in large cities;

5. the protection ratios required to give satisfactory reception for 99% of the time, in systems using a maximum frequency deviation of ± 75 kHz, are those given by the continuous curve in Fig. 1. For steady interference, it is desirable to provide the higher degree of protection, shown by the dashed curve in Fig. 1.

   The corresponding values for systems using a maximum frequency deviation of ± 50 kHz are given in Fig. 2.

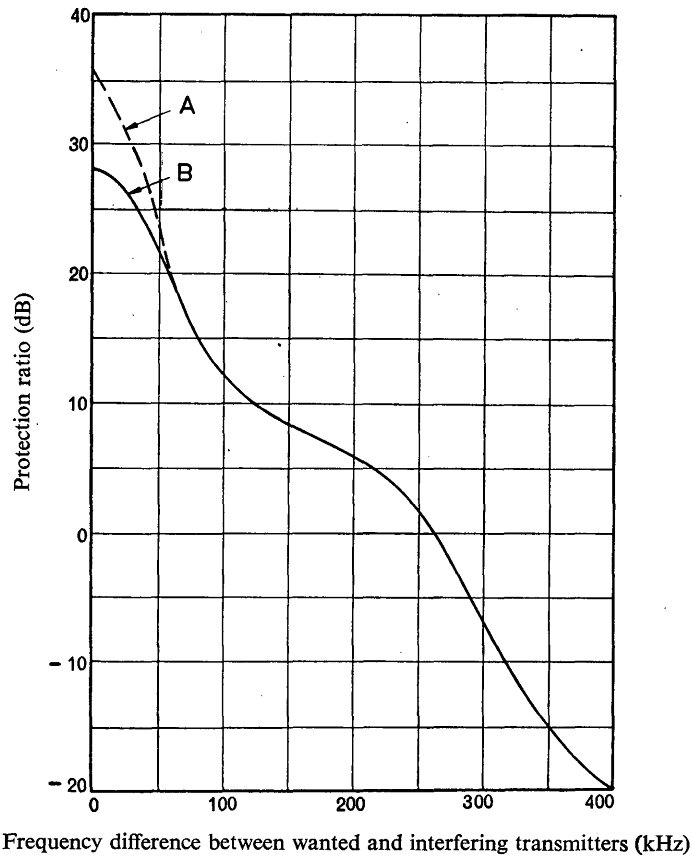

FIGURE 1

Protection ratios required by broadcasting services in band 8 (VHF) at frequencies between 87·5 MHz and 108 MHz using a maximum frequency deviation of ± 75 kHz

Curve A: steady interference

Curve B: tropospheric interference (99% of the time)

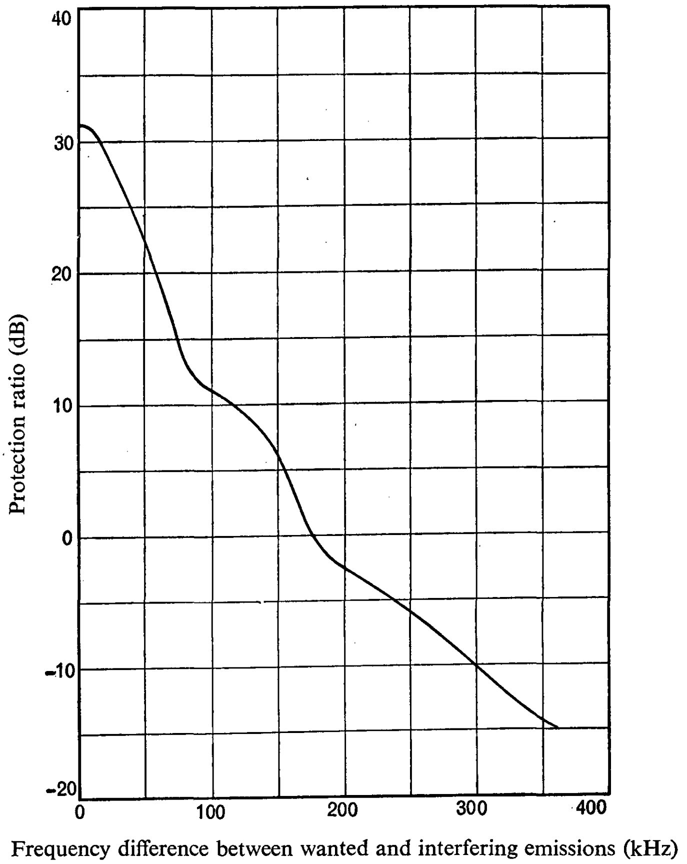

FIGURE 2

Protection ratios required by frequency-modulation sound broadcasting in band 8 (VHF) at frequencies below 87·5 MHz using a maximum frequency deviation of ± 50 kHz

(Tropospheric interference, 99% of the time)

RECOMMENDATION 450

SYSTEMS FOR FREQUENCY-MODULATION STEREOPHONIC BROADCASTING IN BAND 8 (VHF)

The C.C.I.R., (1966)

CONSIDERING

(a) that it is technically possible to transmit stereophonic programmes by a single frequency-modulation transmitter;

(b) that, as far as possible, the introduction of these transmissions should not impair any aspects of existing monophonic reception;

(c) that such transmissions should be capable of rendering a high quality of stereophonic reproduction;

(d) that several systems exist that fulfil these requirements and are compatible within the definition contained in Question 15/10;

(e) that theoretical studies as well as experiments have been carried out with a number of these systems;

(f) that favourable operational results have been obtained with only two of the systems (see Report 300-2);

(g) that international standardization would enhance the development of stereophonic broadcasting;

UNANIMOUSLY RECOMMENDS

that stereophonic transmissions in band 8 (VHF) should be made, using one of the two systems defined by the following specifications which concern components of the signal used to frequency-modulate the transmitter;

1. Polar-modulation system

(maximum frequency deviation: ± 50 kHz or ± 75 kHz).

1.1 a compatible signal, *M*, equal to one half of the sum of the left-hand signal, *A*, and the right-hand signal, *B*, produces deviation of the main carrier by not more than 80% of the maximum frequency deviation for monophonic transmission;

1.2 a signal, *S*, equal to one half the difference between the left-hand and right-hand signals is used to obtain the sidebands of an amplitude-modulated partly suppressed sub-carrier;

1.3 the frequency of the sub-carrier is 31·250 kHz ± 2 Hz;

1.4 the maximum modulation depth of the sub-carrier, before its suppression, is 80%;

1.5 the suppression ratio of the sub-carrier is — 14 dB, the suppression is effected by a resonant circuit having a Q-factor of 100;

1.6 the residual sub-carrier produces a deviation of the main carrier which is 20% of the maximum frequency deviation for the monophonic transmission;

2. Pilot-tone system

(maximum frequency deviation: ± 75 kHz or ± 50 kHz).

2.1 a compatible signal, *M*, equal to one half the sum of the left-hand signal, *A*, and the right-hand signal, *B*, produces a deviation of the main carrier of not more than 90% of the maximum frequency deviation for monophonic transmission;

2.2 a signal, *S*, equal to one-half the difference between the left-hand and right-hand signals is used to obtain the sidebands of an amplitude-modulated suppressed sub-carrier. The sum of these sidebands produces a peak deviation of the main carrier of the same amount as the signal *S* would give if applied to the channel, *M*. The peak deviation is not more than 90% of the maximum frequency deviation for monophonic transmission;

2.3 the frequency of the sub-carrier is 38 000 ± 4 Hz;

2.4 the residual sub-carrier produces a deviation of the main carrier of not more than 1% of the maximum frequency deviation for monophonic transmission;

2.5 a pilot signal having frequency equal to one half of that of the sub-carrier produces a deviation of the main carrier between 8% and 10% of the maximum frequency deviation for monophonic transmission;

2.6 the pre-emphasis of the signal S is identical with that of the compatible signal M;

2.7 the phase relationship between the pilot signal and the sub-carrier is such that when modulating the transmitter with a multiplex signal for which A is positive and B equals $-A$, this signal crosses the time axis with a positive slope each time the pilot signal has an instantaneous value of zero. The phase tolerance of the pilot signal should not exceed $\pm 3°$ from the above state. Moreover, a positive value of the multiplex signal corresponds to a positive frequency deviation of the main carrier;

2.8 if it is desired to transmit a supplementary monophonic programme simultaneously with a stereophonic programme and the maximum frequency deviation is $\pm$ 75 kHz, the following additional specification applies:

2.8.1 the stereophonic multiplex signal deviates the main carrier by not more than 90% of the maximum frequency deviation for monophonic transmission;

2.8.2 the instantaneous frequency of the frequency-modulated supplementary sub-carrier is within the range of 53 to 75 kHz;

2.8.3 the modulation of the main carrier by the supplementary sub-carrier is not more than 10%.

Note. — (Added at the request of the Administration of Sweden). Countries which find it essential to use a stereophonic system capable of transmitting two separate monophonic programmes when the equipment is not used for stereophony (see Report 300-2, § 2.8), may also take into consideration the FM/FM compressor/expander system described in § 3.3 of the same Report.

RECOMMENDATION 467

TECHNICAL CHARACTERISTICS TO BE CHECKED FOR FREQUENCY-MODULATION STEREOPHONIC BROADCASTING

Pilot-tone system

(Question 16/10, Study Programme 16A/10)

The C.C.I.R. (1970)

UNANIMOUSLY RECOMMENDS

1. that during programme transmission instruments should indicate the percentage of peak-modulation in the main carrier by the following:

1.1 the main channel, M;

1.2 the stereophonic sub-carrier, S;

1.3 the pilot signal;

1.4 all signals, specified in Recommendation 450, simultaneously;

2. that in addition, the following characteristics should be measured during periods of test and adjustment:

2.1 the frequency response of the M and individual A and B channels;

2.2 harmonic distortion in the individual *A* and *B* channels;

2.3 the signal-to-noise ratio in the individual *A* and *B* channels;

2.4 the crosstalk attenuation between the *A* and *B* channels;

2.5 the crosstalk from the main channel, *M*, into the stereophonic sub-channel, *S*, and from the stereophonic sub-channel, *S*, into the main channel;

2.6 the frequency of the pilot signal;

2.7 the degree of suppression of the sub-carrier;

2.8 the phase of the sub-carrier relative to the pilot signal;

2.9 the total unintentional amplitude-modulation of the main carrier.

10B: *Reports*

REPORT 300-2 *

STEREOPHONIC BROADCASTING

(Question 15/10 and Study Programme 15A/10)

(1963 – 1966 – 1970)

1. Introduction

Since the XIth Plenary Assembly of the C.C.I.R. Oslo, 1966, certain Administrations and broadcasting organizations have conducted theoretical and experimental work relating to stereophonic broadcasting. As a result of this work, stereophonic transmissions intended for the public, using single frequency-modulation transmitters, were introduced in a number of countries.

This Report summarizes the situation concerning stereophonic broadcasting systems on the basis of the documents listed in the Annex.

2. Desirable basic characteristics of a system for stereophonic broadcasting

It is generally agreed that the principal desirable characteristics of any system for stereophonic broadcasting using a single radio-frequency channel, are as follows:

2.1 the system should be compatible; that is to say, it should be possible to obtain monophonic reception of a stereophonic transmission, without reduction of quality in comparison with the reception of the normal monophonic transmission;

2.2 the system should provide high-quality stereophonic reproduction (see Report 293-2);

2.3 it should be possible to construct stereophonic receivers at reasonably economic prices;

2.4 the introduction of stereophonic transmissions, at an existing monophonic broadcasting station, should not significantly reduce the service area of the station for monophonic reception;

2.5 the service area of the broadcasting station for stereophonic reception should be as nearly as possible equal to that for monophonic reception;

2.6 the protection against interference required for stereophonic reception should not be substantially greater than that for monophonic reception;

2.7 the introduction of the stereophonic system should not necessitate extensive changes in the existing frequency-assignment plans;

2.8 according to some Administrations, the system should be capable, when not used for stereophonic broadcasting, of transmitting two separate monophonic programmes such as, for example, speech in two different languages. However, other Administrations, while agreeing that this characteristic is desirable, do not consider it to be essential.

3. Results of tests on systems

3.1 *Polar-modulation system*

The system of stereophonic broadcasting, using polar-modulation with partly suppressed sub-carrier, was developed in the U.S.S.R. and has been in service in that country

* This Report was adopted unanimously.

since 1959. The system ensures a high quality of sound reproduction and good compatibility with monophonic broadcasting.

For the period 1959 to 1964, additional studies and experiments have been carried out and new decoding circuits have been developed, as a result of which there has been further improvement of the system. Moreover, this system has been tested within the framework of the O.I.R.T. and found to provide high-quality monophonic and stereophonic reception. The Technical Commission of the O.I.R.T., in its Recommendation No. 45, suggested the use of the polar-modulation system in the O.I.R.T. member countries.

The polar-modulation system can be used with maximum frequency deviations of ± 50 kHz and ± 75 kHz. It is defined by the specifications in Recommendation 450.

3.1.1 *Compatible monophonic reception*

As a result of tests, compatible monophonic reception by the polar-modulation system may be characterized by the test results given below as observed at the output of a typical domestic receiver.

3.1.1.1 Audio-frequency response: the same as for monophonic service.

3.1.1.2 Intermodulation S to M: — 44 dB.

3.1.1.3 Total harmonic distortion: equal to or slightly greater than the value for monophonic transmission.

3.1.1.4 Non-linear crosstalk S to M: better than — 39 dB.

3.1.1.5 Signal-to-noise (weighted) ratio: 1 to 2 dB worse than for monophonic transmission.

3.1.1.6 Radio-frequency protection-ratio: almost equal to that for reception of a monophonic transmission, whether the interfering transmission is monophonic or stereophonic.

3.1.2 *Stereophonic reception*

Stereophonic reception by the polar-modulation system may be characterized by the following results observed at the output of a typical domestic receiver.

3.1.2.1 Audio-frequency response: the same as for monophonic service.

3.1.2.2 Linear crosstalk between A and B:

between 300 Hz and 5 kHz:	better than — 30 dB
between 60 Hz and 300 Hz and 5 kHz and 10 kHz:	better than — 20 dB
between 30 Hz and 60 Hz and between 10 kHz and 15 kHz:	better than — 12 dB

3.1.2.3 Total harmonic distortion: not greater than 1%.

3.1.2.4 Non-linear crosstalk between A and B: better than — 39 dB.

3.1.2.5 Signal-to-noise (weighted) ratio: 9 to 19 dB worse than for monophonic service.

3.1.2.6 Radio-frequency protection ratios relative to the values used for monophonic transmission: for a deviation of ± 50 kHz as a function of the separation Δf of the carrier frequencies.

$\Delta f = 0$: increase of about 10 dB;

$\Delta f =$ 30 to 60 kHz: increase of about 18 dB;

$\Delta f =$ 135 kHz : no change.

3.2 *Pilot-tone system*

During the period 1959 to 1966, detailed studies of a system of stereophonic broadcasting, the service performance characteristics of which are given in §§ 3.2.1 to 3.2.5, were carried out independently in many countries. These studies have comprised theoretical analyses, laboratory tests, actual service trials and listening tests before and after high-frequency transmission, with the object of evaluating not only the subjective quality of stereophonic reception but also that of compatible monophonic reception. The results and conclusions drawn from the tests are given in the documents listed in the Annex.

In the United States of America, the tests were carried out by the National Stereophonic Radio Committee with the collaboration of many industrial firms. The tests were carried out on six systems from which only the pilot-tone system was retained and put into regular service in 1961.

In Europe, the tests were coordinated by the E.B.U. and were carried out by five broadcasting organizations; in addition seven industrial laboratories took part in the first series of measurements. Tests were made on ten systems and, of these, the pilot-tone system was considered to be the best. More detailed tests on this system have been continued to date. Tests have also been made on this system within the framework of the O.I.R.T., the Technical Commission of which in its Recommendation No. 45 suggested the use of this system in the O.I.R.T. member countries.

Nine countries have commenced a regular stereophonic service using the pilot-tone system because they considered that this system best complied, on the whole, with the conditions set out in § 2 of this Report.

The pilot-tone system has been tested with maximum frequency deviations of ± 75 kHz and ± 50 kHz. It is defined by the specifications in Recommendation 450.

3.2.1 *Compatible monophonic reception*

As a result of tests, compatible monophonic reception, by the pilot-tone system may be characterized by the test results given below as observed at the output of a typical domestic receiver.

3.2.1.1 Audio-frequency response: same as for monophonic service.

3.2.1.2 Linear crosstalk: S to M: — 60 dB below 1 kHz
— 44 dB from 1 to 15 kHz.

3.2.1.3 Intermodulation: S to M: equal to or better than — 40 dB.

3.2.1.4 Total harmonic distortion: equal to or slightly greater than the value for monophonic transmission.

3.2.1.5 Non-linear crosstalk S to M: better than — 40 dB.

3.2.1.6 Signal-to-noise (weighted) ratio: 66 to 76 dB for an input level of — 54 dBmW.

3.2.1.7 Beat-frequency interference: better than — 50 dB.

3.2.1.8 Radio-frequency protection ratio: 0 to 3 dB higher than for monophonic reception for a carrier frequency separation between 0 and 300 kHz.

3.2.1.9 Multipath propagation effects: almost equivalent to a monophonic transmission.

3.2.1.10 Sensitivity to impulse noise: almost equivalent to that for monophonic transmission.

3.2.2 *Stereophonic reception*

Stereophonic reception by the pilot-tone system may be characterized by the following results observed at the output of a typical domestic receiver.

It is possible, however, to improve most of the following results by using better receiving installations, notably by using a decoder containing:

— a low-pass filter inserted in the multiplex channel, having a relatively sharp cut-off above 53 kHz;

— a filter to attenuate unwanted frequencies close to 19 kHz;

— an amplitude-modulation limiter for the pilot signal in the sub-carrier reconstitution circuits.

The figures in parenthesis refer to these improved receivers.

3.2.2.1 Audio-frequency response: the same as for monophonic service.

3.2.2.2 Linear crosstalk between A and B: better than — 20 dB at frequencies up to 15 kHz and better than — 35 dB between 100 Hz and 3 kHz independent of the receiver input level.

3.2.2.3 Intermodulation between A and B: — 45 dB at 1 kHz; — 30 dB at 15 kHz (— 45 dB from 50 Hz to 15 kHz).

3.2.2.4 Total harmonic distortion: equal to or slightly greater than the value for monophonic transmission.

3.2.2.5 Non-linear crosstalk between A and B: better than — 40 dB.

3.2.2.6 Signal-to-noise (weighted) ratio: 58 to 64 dB for an input level to the receiver of 54 dBmW.

3.2.2.7 Beat-frequency interference: better than — 50 dB.

3.2.2.8 Radio-frequency protection ratio as a function of the separation Δf of the carrier frequencies:

$\Delta f = 0$: of the same order as the value 36 dB adopted for monophonic transmission;

$\Delta f =$ 50 kHz: between 50 and 55 dB (42 dB); it is clearly desirable to avoid the use of frequency separation of 50 kHz for stereophonic services;

$\Delta f =$ 100 kHz: between 25 and 30 dB (17 dB), the value for monophonic transmission being 12 dB;

$\Delta f =$ 200 kHz: equal to or less than the value of 6 dB adopted for monophonic transmission.

3.2.2.9 Multipath propagation effects: satisfactory if the signal-to-echo ratio, at the receiver input, is equal to or greater than 16 dB. (It is possible to have an improvement of 20 dB relating to the distortion due to unwanted components appearing outside the band occupied by modulation signals, these components being responsible for an appreciable part of the disturbance observed in the presence of multipath propagation).

3.2.2.10 Sensitivity to impulse noise: satisfactory reception, if the field strength is greater than a value between 250 μV/m and 1 mV/m, depending on the regulations in different countries applying to the suppression of interference.

3.2.3 *Transmission and reception of independent monophonic programmes in the M and S channels having an audio-frequency bandwidth of 15 kHz and equal maximum modulation depth*

3.2.3.1 Overall crosstalk (linear and non-linear) S to M: — 45 dB.

3.2.3.2 Overall crosstalk (linear and non-linear) M to S: — 55 dB.

The presence of multipath propagation can degrade these figures by 10 dB or more.

3.2.4 *Direct re-broadcasting of stereophonic programmes*

No difficulties were encountered in transmitting over three links in tandem.

It was also found possible, with the pilot-tone system, to provide for the international exchange of high-quality stereophonic programmes using a communications space satellite system.

3.2.5 *Variants of the pilot-tone system*

A variant of the pilot-tone system has been investigated in the Netherlands using a single-sideband modulation of the sub-carrier, having a vector amplitude twice that of the sidebands generated in the case of normal sub-carrier modulation, making it compatible for stereophonic receivers having a synchronous type of decoder. The variant could offer interesting applications in certain circumstances, while maintaining the normal receiving and decoding principles.

3.3 *The FM-FM system using a compressor/expander in the S-channel*

In the documents listed in § 3 of the Annex, results are given of tests on a number of systems using a compressor for the S-channel in the transmitter and a corresponding expander in the receiver. These tests were carried out with an FM-AM system, a pilot-tone system and an FM-FM system. The results obtained have shown that noise in the *S*-channel is considerably suppressed by the compressor/expander. Recent tests have furthermore shown that, when transmitting two independent monophonic programmes, only the FM-FM system can give sufficiently low crosstalk from the *S*-channel, into the *M*-channel. The FM-FM system is defined by the following specifications:

3.3.0.1 a compatible signal *M* produces a deviation of the main carrier of not more than 80% of the maximum frequency deviation for monophonic transmissions; in the case of two-programme transmission, the deviation is equal to that of the first programme signal and in the case of stereophonic transmissions, equal to one half the sum of the left-hand signal *A* and the right-hand signal *B*;

3.3.0.2 a signal *S* produces frequency-modulation of a sub-carrier in case of two-programme transmissions equal to the second programme signal and in case of stereophonic transmissions, equal to one half the difference between the left-hand signal *A* and the right-hand signal *B*;

3.3.0.3 the frequency of the sub-carrier is 33·3 kHz ± 100 Hz;

3.3.0.4 the maximum frequency deviation of the sub-carrier is ± 10 kHz;

3.3.0.5 the sub-carrier produces a deviation of the main-carrier between 18% and 20% of the maximum frequency deviation for monophonic transmissions;

3.3.0.6 the pre-emphasis of the *S*-signal is identical to that of the compatible *M*-signal;

3.3.0.7 a compressor with transfer ratio 2/1 (in dB) is inserted in the *S*-channel of the transmitter before the pre-emphasis network, this compressor has time-constants respectively equal to 2 ms for the rise-time and 20 ms for the decay-time;

3.3.0.8 an expander with characteristics reciprocal to those of the compressor, is inserted in the *S*-channel of the receiver after the de-emphasis network;

3.3.0.9 in stereophonic transmissions, an *A*-signal produces a frequency deviation in the same direction for the sub-carrier and the main carrier;

As a result of tests carried out by the Swedish Telecommunications Administration, the performance of the system may be characterized by the typical results given below as obtained at the output of a typical domestic receiver. *

3.3.1 *Compatible monophonic reception*

3.3.1.1 Audio-frequency response: same as for monophonic service.

3.3.1.2 Linear crosstalk *S* to *M*: better than — 60 dB up to 10 kHz.

3.3.1.3 Intermodulation *S* to *M*: better than — 60 dB up to 10 kHz.

3.3.1.4 Total harmonic distortion: equivalent to that for monophonic transmission.

3.3.1.5 Non-linear crosstalk *S* to *M*: better than — 60 dB up to 10 kHz when transmitting two different programmes and better than — 50 dB up to 10 kHz when transmitting stereophonic programmes.

3.3.1.6 Signal-to-noise (weighted) ratio: 2 dB less than for monophonic transmission.

3.3.1.7 Radio-frequency protection ratio as a function of the separation Δf between the carrier frequencies:

$\Delta f =$ 0 : almost equivalent to that for monophonic transmission;

$\Delta f =$ 50 kHz: higher than that for monophonic transmission, but less than 24 dB;

$\Delta f =$ 100 kHz: equivalent to that for monophonic transmission;

$\Delta f =$ 200 kHz: equivalent to that for monophonic transmission.

3.3.1.8 Multipath propagation effects: equivalent to that for monophonic transmission.

3.3.1.9 Sensitivity to impulsive noise: almost equivalent to that for monophonic transmission.

3.3.2 *Monophonic reception of the* S-*channel*

3.3.2.1 Audio-frequency response: same as for monophonic service.

3.3.2.2 Linear crosstalk *M* to *S*: better than — 60 dB up to 10 kHz.

3.3.2.3 Intermodulation *M* to *S*: better than — 60 dB up to 10 kHz.**

3.3.2.4 Total harmonic distortion: equivalent to that for monophonic transmission.

3.3.2.5 Non-linear crosstalk *M* to *S*: better than — 60 dB up to 10 kHz.

3.3.2.6 Signal-to-noise (weighted) ratio: at 1% of the maximum audio input level equivalent to that for monophonic transmission, then changing gradually to 20 dB below the value for monophonic transmission at 100% audio-frequency input level.

3.3.2.7 Radio-frequency protection ratio as a function of the separation Δf between the carrier frequencies:

$\Delta f =$ 0 : less than that for monophonic transmission;

$\Delta f =$ 50 kHz: equivalent to that for monophonic transmission with $\Delta f = 0$;

$\Delta f =$ 100 kHz: slightly higher than that for monophonic transmission but less than 15 dB; (a lower figure than 15 dB can be obtained by using an additional filter circuit in the decoder, which filter circuit is suppressing the interfering components around 100 kHz);

$\Delta f =$ 200 kHz: equivalent to that for monophonic transmission.

* Other Administrations have not been able to confirm all these results.

** 100% utilization factor in one channel, 30% in the other.

3.3.2.8 Multipath propagation effects: slightly worse than for monophonic transmission (mainly non-linear crosstalk from *M*).

3.3.2.9 Sensitivity to impulsive noise: equivalent to that for monophonic transmission.

3.3.3 *Stereophonic reception*

3.3.3.1 Linear crosstalk between *A* and *B*: better than — 30 dB up to 5 kHz and better than — 25 dB up to 10 kHz.

3.3.3.2 Intermodulation between *A* and *B*: better than — 40 dB at 1 kHz and 10 kHz.

3.3.3.3 Non-linear crosstalk between *A* and *B*: better than — 40 dB.

4. Comparative field tests of the pilot-tone system and the FM-FM compressor-expander system

In Doc. X/27 (Sweden), 1966–1969, a field test is decribed giving the opinions of a number (103) of specially selected listeners on the comparative qualities of the two stereophonic systems. According to this document, the test showed that the FM-FM system gives higher quality than the pilot-tone system. The difference in quality was judged to be moderate in the neighbourhood of the transmitter but considerable in the outer part of the service area. This was mainly due to the difference in noise and CW-interference, but also to more frequent distortion on the pilot-tone system than on the FM-FM compressor-expander system. The subjectively judged stereo separation was the same for both systems.

Doc. X/149 (U.S.A.), 1966–1969, describes a field test carried out to compare the two systems. The test showed that listeners preferred the pilot-tone system with regard to noise, distortion and overall impression. The distortion in the FM-FM system was caused by non-linear phase response in the sub-channel, its band-limited nature and the compandor effect upon turn-table rumble. During stereophonic modulation the FM-FM system noise is inherently slightly worse. This may be due to its poorer main and sub-channel modulation characteristics. When no modulation exists the pilot-tone system is noisier due to sub-channel noise being present.

The difference in results between the two tests as reported in Docs. X/27 and X/149 may be explained by the fact that the apparatus used was not of the same construction for either system. In addition the tests described in Doc. X/149 involved sequential comparison wherein the transmitter switched the systems every 15 s and all listeners were judging the same condition from the same receiver at one location at any given time. Four different programmes were used. For the tests described in Doc. X/27, on the other hand, listeners were hearing separate receivers at different locations and judging at separate times, each listener judging 20 different programmes which were broadcast in both systems in mixed order.

5. Conclusions

Bearing in mind the desirable characteristics for a system of stereophonic broadcasting set out in § 2 of this Report, and taking into account the results contained in documents listed in the Annex, it would appear that the polar-modulation system and the pilot-tone system meet in service the requirements of § 2.1 (compatibility), § 2.2 (quality), § 2.4 (monophonic coverage), § 2.5 (stereophonic coverage), § 2.6 (protection against interference) and § 2.7 (frequency assignment plans). Experience of industrial manufacturing in countries where these systems are operating has shown that the corresponding stereophonic receivers meet the requirement of § 2.3 (reasonable cost).

Finally, the FM-FM system with amplitude compression/expansion has been extensively tested in only one country and further studies seem to be necessary.

For these reasons, although some difficulties remain concerning the condition of § 2.8 (transmission of independent programmes), Study Group 10 is of the opinion that either the polar-modulation system or the pilot-tone system, as indicated in Recommendation 450, can be proposed for a stereophonic broadcasting service.

ANNEX

DOCUMENTS CONCERNING STEREOPHONIC BROADCASTING SYSTEMS

Note. — The list given below indicates, for each system described in the present Report, the various documents submitted to the Interim Meetings of Study Group X in 1962, 1965 and 1968 and to the Xth and XIth Plenary Assemblies of the C.C.I.R. (1963 and 1966). Documents dealing with more than one system are listed under each corresponding heading.

1. Polar-modulation system

Doc. 238 (U.S.S.R.), Geneva, 1963	VHF-FM stereophonic broadcasting.
Doc. X/54 (O.I.R.T.), 1963–1966	Stereo broadcasting. Reduction of the zone of coverage due to random and pulse interference.
Doc. X/63 (O.I.R.T.), 1963–1966	Opinion of the O.I.R.T. on the choice of a system for stereophonic broadcasting.
Doc. X/70 (O.I.R.T.), 1963–1966	Radio transmission of two signals by means of a VHF transmitter using an AM sub-carrier.
Doc. X/162 (U.S.S.R.), 1963–1966	Basic results of tests with polar-modulation stereophonic broadcasting systems.
Doc. X/163 (U.S.S.R.), 1963–1966	Some stereophonic detector circuits for polar-modulation stereophonic broadcasting systems.

2. Pilot-tone system

Doc. X/28 (E.B.U.), Bad Kreuznach, 1962	Choice of a standardized system of stereophonic broadcasting on metric waves.
Doc. X/35 (U.S.A.), Bad Kreuznach, 1962	Stereophonic broadcasting standards for compatible systems in sound and television broadcasting.
Doc. 205 (E.B.U.), Geneva, 1963	Technical results of the tests on the service area of the suppressed sub-carrier stereophonic system.
Doc. 223 (Japan), Geneva, 1963	Stereophonic broadcasting standards for compatible systems.
Doc. 309 (E.B.U.), Geneva, 1963	Choice of a standardized system of stereophonic broadcasting on metric waves.
Doc. X/13 (Canada), 1963–1966	Stereophonic broadcasting for frequency-modulation sound systems using a maximum frequency deviation of 75 kHz.
Doc. X/16 (Netherlands), 1963–1966	Stereophonic broadcasting. A single-sideband variant of the pilot-tone system of stereophonic broadcasting.

Doc. X/20 (United Kingdom), 1963–1966	Stereophonic broadcasting. The effect on population coverage of introducing the pilot-tone system of stereophonic broadcasting into the United Kingdom VHF-FM service.
Doc. X/22 (U.S.A.), 1963–1966	Two separate programmes with the pilot-tone system.
Doc. X/23 (U.S.A.), 1963–1966	Protection ratios for stereophonic broadcasting.
Doc. X/42 (E.B.U.), 1963–1966	Stereophonic broadcasting. Results of further technical tests.
Doc. X/45 (F. R. of Germany), 1963–1966	Standards for stereophonic broadcasting.
Doc. X/53 (O.I.R.T.), 1963–1966	Reduction of the service area of a VHF transmitter on transition from monophonic to stereophonic transmissions or in the case of two-programme transmissions using an AM sub-carrier procedure.
Doc. X/55 (O.I.R.T.), 1963–1966	On the usability of monophonic receivers for compatible reception of stereophonic broadcasts and of the main channel in the case of two-programme transmissions.
Doc. X/62 (U.S.A.), 1963–1966	The pilot-tone system for countries using ± 50 kHz deviation.
Doc. X/63 (O.I.R.T.), 1963–1966	Opinion of the O.I.R.T. on the choice of a system for stereophonic broadcasting.
Doc. X/69 (U.S.A.), 1963–1966	The relay of stereophonic programmes by a satellite using the pilot-tone system.
Doc. X/70 (O.I.R.T.), 1963–1966	Radio transmission of two signals by means of a VHF transmitter using an AM sub-carrier.

3. Systems using an amplitude compandor in the S channel

Doc. X/24 (Sweden), Bad Kreuznach, 1962	Stereophonic broadcasting.
Doc. 166 (Sweden), Geneva, 1963	Stereophonic broadcasting.
Doc. X/14 (Sweden), 1963–1966	Stereophonic broadcasting. Simultaneous transmission of two-sound channels in television.
Doc. X/42 (E.B.U.), 1963–1966	Stereophonic broadcasting. Results of further technical tests.
Doc. X/129 (Sweden), 1963–1966	Comments on the texts relating to the work of Study Group X.
Doc. X/27 (Sweden), 1966–1969	A comparative test of the FM-FM compressor-expander system and the pilot-tone system for stereophonic broadcasting.

REPORT 403-1 *

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND CHANNELS IN TELEVISION

(Question 18-1/10 and Study Programme 18-1A/10)

(1966 – 1970)

1. Existing systems

For the transmission of only two sound channels in television two basically different types of system are proposed. One system uses an additional sound carrier, some 250 kHz above the normal sound carrier, both being multiplexed into one single sound transmitter; other systems make use of a sub-carrier in the normal sound channel. This sub-carrier can be modulated in frequency or in amplitude. When the modulated sub-carrier and the original audio-frequency signal together frequency-modulate the sound carrier we have FM-FM or FM-AM systems respectively.

Amplitude-modulated sub-carriers are synchronized to the line-frequency or to a frequency that is simply related to it (1, 3/2, 2, 5/2 times the line-frequency). For frequency-modulated sub-carriers the centre-frequency is close to one of these multiples of the line-frequency.

To improve the signal-to-noise ratio in the second sound channel, compression and expansion can be used.

In the FM-AM system the sub-carrier can be suppressed. In this case the line-frequency is usually used as a pilot-tone, but a separate pilot-tone has also been provided. Instead of double-sideband amplitude-modulation of the sub-carrier, single-sideband modulation with a suppressed sub-carrier is also used.

In the systems so far discussed, the first programme is transmitted in the normal way. In the system that was used in Algeria by France, both sound programmes were transmitted in time-division multiplex by pulse-amplitude modulation, the pulses being synchronized with a line-frequency of 20.475 kHz.

1.1 *Choice of sub-carrier frequency*

The reason why some countries favour the use of an odd multiple of half the line-frequency for the sub-carrier frequency is to reduce interference from the picture signal into the second channel, when a simple multiple of the line-frequency is used for this purpose (especially when inter-carrier sound reception is used).

An advantage of the use of 3/2 the line-frequency for the sub-carrier in combination with single-sideband is the relatively narrow frequency spectrum, which facilitates the use of ordinary television sound receivers and avoids certain forms of interference. A disadvantage of the choice of an odd multiple of half the line-frequency for the sub-carrier frequency is that only modulation frequencies up to 7000 Hz can be admitted if the quality of the first channel is to be maintained. The choice of a higher multiple of the line-frequency for the sub-carrier frequency offers the possibility of wideband modulation, but FM-AM systems that make this choice are more sensitive to interference from the line-frequency harmonic. Frequency-modulation in the picture channel may be a source of interference but this is avoided in modern transmitters. In receiving a television signal of the vestigial-sideband type on inter-carrier sets, phase variation of the video sideband signal is mainly caused by the Nyquist slope in the receiver. Several possibilities for reducing the undesirable effects of this

* This Report was adopted unanimously.

interference are being studied (e.g. compensation by means of a connection from the video detector output to the frequency-modulation detector output via an isolating stage). In an FM-AM system studied in Poland and Japan, to avoid interference in inter-carrier system receivers caused by the second harmonic of the line-frequency, modulated by the field-frequency, a shift of 90° between the switching voltage of the decoder and the second harmonic of the line-frequency is used. In the systems studied in Japan, the interference caused in inter-carrier system receivers using the FM-FM system is less than in those using the FM-AM system.

1.2 *Frequency-deviation and other system characteristics*

In the FM-AM system studied in the People's Republic of Poland, both channels deviate the main carrier by ± 25 kHz. In the FM-FM and the FM-AM systems studied in Japan the first channel deviates the main carrier by ± 25 kHz and the second channel by ± 15 kHz. In the Swedish FM-FM system the second channel has a deviation of only ± 10 kHz (main channel ± 40 kHz), but its dynamic range is compressed 2/1 in dB, with time constants of 2 ms for the rise time and 20 ms for the decay time. For the system used in the U.S.S.R. (single-sideband modulation of the sub-carrier) the first channel is allowed a frequency deviation of ± 40 kHz and the second channel a frequency deviation of ± 15 kHz.

In the French system, the width of the pulses is 8 to 10 μs, the rise-time 4 μs (approximately) and the delay with respect to the line synchronization pulse is respectively 5 μs (in channel 1) and 24 μs (in channel 2). Time-division multiplex may be possible with frequency-modulation sound too, but this needs further study. This system requires only very small changes in existing receivers. It has the advantage of treating both sound channels in an identical manner, but it does not permit the reception of one sound channel without any modification of the receiver (Question 18-1/10, § 1). This requirement is met by the other systems discussed.

In the Netherlands an FM-AM system has been studied using the line-frequency itself as suppressed sub-carrier. By selecting the lower sideband of the modulated sub-carrier the bandwidth of the multiplex signal is not substantially greater than 15 kHz; both audio-frequency signals are however restricted to 6·3 kHz limiting its application. The level of the single-sideband signal has been taken 7 dB below the level of the primary signal.

2. Required modifications to receivers

The modification to existing receivers necessary to allow the choice of either sound channel is the inclusion of a relatively small adaptor. This adaptor may contain only 1 switch, 2 diodes, 1 resistor and 1 coil, as in the French system, or it may use 3 coils, 9 transistors and 4 diodes, as in the Swedish system. The other systems are in between these two with regard to this requirement.

When adapting existing receivers to a second sound channel one has to see that the first detector is sufficiently wideband. Interference to the adjacent channel, crosstalk, distortion and deterioration of signal-to-noise ratio should also be carefully watched.

3. Stereophony

Compatibility with existing receivers would necessitate modulation of the main sound channel by the $A + B$ signal. High quality requirements may put systems with a reduced bandwidth in the second channel at a disadvantage and make them less suitable for stereophony. Tests carried out in Japan showed that the audio-frequency response and the stereophonic separation between the A and B signals in the FM-FM system were better than those in the FM-AM (single-sideband) system.

4. Service area

In the compression-expansion FM-FM system studied in Sweden, the second sound channel was found to have about the same service area as the first sound channel, almost equivalent to the service area of monophonic one-channel transmission. In most other systems, one would expect a smaller service area for the second sound channel compared with the first and also for the first channel compared with ordinary monophonic transmission (because of reduced frequency deviation and because of the triangular FM noise characteristics before de-emphasis).

In the Japanese system, however, the first channel is expected to have the same service area as the ordinary monophonic transmission if the same frequency deviation is maintained. The French system gives both sound channels the same quality, but it is not easy to see whether their service areas are also the same as those of conventional amplitude-modulation systems.

5. Crosstalk

The crosstalk between the two sound channels can be better than —40 dB. For the Swedish system values of better than —60 dB are quoted. For some of the other systems no precise data are as yet available.

In Japan, a method has been developed of measuring the crosstalk by means of specially filtered white noise, giving objective results representative of the subjective grade of this effect in cases where the crosstalk is predominant.

The method has been used in measurements with several television receivers using the Japanese system. The results are as follows:

Crosstalk in the first channel from the second channel:

FM-FM	—57 to —63 dB
FM-AM (single-sideband)	—48 to —57 dB

Crosstalk in the second channel from the first channel (without compressor/expander):

FM-FM	—47 to —51 dB
FM-AM (single-sideband)	—50 to —52 dB

6. Compatibility

Investigations made in Sweden show that with old receivers the risk of sound interference in the compatible sound channel when a second channel is used, is minimized when the sub-carrier frequency is close to one of the harmonics of the picture line frequency, that is to avoid audible beat-tones produced by intermodulation between the sub-carrier and mentioned harmonics. It is also found that it is better to use a sub-carrier frequency close to the second harmonic of the line frequency than to the third harmonic as with the latter frequency a higher degree of amplitude-modulation will arise in the sound intermediate part of the receiver.

7. Inter-carrier or split-carrier receivers (see Note)

Tests carried out in Sweden have shown that for high quality with an audio-frequency response up to 15 kHz, a split-carrier receiver should be used. The split-carrier will not only improve reception of the second channel but also of the first channel.

To avoid any interference when using inter-carrier receivers it was found necessary to limit the audio-frequency response of the second channel to 7 kHz.

Laboratory tests and experimental broadcast transmissions in Japan using a sub-carrier locked to the second multiple of the line frequency show that when using inter-carrier receivers it is possible to have an audio-frequency response up to 12 kHz. This may be partly explained by the fact that in the Japanese system both the amplitude and deviation of the sub-carrier is larger than that used in the Swedish tests, thereby giving an improvement in signal-to-noise ratio of 6 dB.

Another method of obtaining high quality is reported from Sweden. This method uses a converter in the television receiver, changing the television sound intermediate frequency for reception of sound broadcasting in band 8 (VHF). Old television receivers can be used and the converter is cheap. However, this method requires that the same multiplex system is used both for television and sound broadcasting in band 8 (VHF).

Note. — Split-carrier receivers are receivers where the channels for vision and sound are independent of each other, that is to say, the difference frequency of the local oscillators is not synchronized as in the case of inter-carrier systems.

8. References

The systems discussed in this Report were described more fully in Doc. X/34 (France), Bad Kreuznach, 1962, and in Docs. X/14 (Sweden), X/46 (Japan), X/144 (Japan), X/57 (People's Republic of Poland), X/61 (U.S.S.R.), 1963–1966, X/32 (Japan), X/58 (Netherlands), X/66 (U.S.S.R.), X/155 (Sweden) and X/169 (Japan), 1966–1969.

REPORT 462 *

STANDARDS FOR FREQUENCY-MODULATION STEREOPHONIC SOUND BROADCASTING IN BAND 8 (VHF)

Pilot-tone system

(1970)

1. Introduction

Recommendation 412 specifies the protection ratios to be used for frequency planning purposes for sound broadcasting band 8 (VHF)—but only in relation to monophonic services. Stereophonic broadcasting, however, demands substantially larger protection ratios, if a grade of service equivalent to that adopted for monophonic broadcasting is to be achieved.

The most critical parameter from the frequency planning aspects is the adjacent channel protection for 100 kHz spaced channels, where in stereophonic broadcasting the required protection ratio may be as high as 30 dB, as compared with the 12 dB specified for monophonic services. This figure can, however, be reduced to about 20 dB by the addition of a low-pass filter following the demodulator in the stereophonic receiver. This filter is designed to reduce interference and noise at frequencies greater than 53 kHz, particularly that occurring near to harmonics of the sub-carrier frequency which might otherwise produce an audio-frequency output in the *A-B* channel.

* This Report was adopted unanimously.

The other important parameter affecting Recommendation 412 is the minimum field strength necessary for satisfactory reception in the presence of man-made noise. Stereophonic reception requires some 12 dB greater protection against such interference than does monophonic reception. The monophonic standards quoted in § 4 of Recommendation 412 were specified in 1956 and have since been used for frequency planning. However, the levels of man-made noise, particularly that produced by motor vehicles, have tended to decrease during the last decade, due to the regulatory action taken by Administrations. Hence, the existing monophonic services have now a greater margin of protection. Listeners to stereophonic transmissions can be expected to improve their receiving installations should interference arise and it is considered that median field strengths some 6 dB greater than those specified for monophonic broadcasting should be satisfactory for stereophonic listening. Where the field strength required for satisfactory monophonic reception is already high, as is the case in large cities, the increase in field strength required for stereophonic listening may be somewhat less than 6 dB.

2. Standards

2.1 The characteristics of the stereophonic transmission should be as defined in Recommendation 450 for the pilot-tone system;

2.2 the pre-emphasis characteristic should be defined as a curve rising with frequency in conformity with the admittance of a parallel combination of a capacitance and a resistance having a time constant of either 50 μs or 75 μs.

3. Minimum field strength

3.1 In the absence of interference from industrial and domestic equipment, a field strength of at least 250 μV/m (measured 10 m above ground level) can be considered to give an acceptable stereophonic service if a multi-element antenna is used;

3.2 in the presence of interference from industrial and domestic equipment a satisfactory stereophonic service requires a median field strength of at least:

0·5 mV/m in rural areas,

2 mV/m in urban areas,

5 mV/m in large cities.

(measured at 10 m above ground level).

4. Protection ratios

The protection ratio required at the receiver input to give satisfactory reception for 99% of the time, in systems using a maximum frequency deviation of ± 75 kHz, is given by the curve B_s in Fig. 1. For steady interference, it is desirable to provide the higher degree of protection shown by the curve A_s. A_m and B_m, the equivalent curves for monophonic services, are reproduced for comparison from Recommendation 412.

Curves A_s and B_s indicate the protection ratio required for a stereophonic service when a low-pass filter, designed to reduce interference and noise at frequencies greater than 53 kHz, follows the stereophonic receiver demodulator.

5. Conclusions

Values have been given for the minimum field strength and protection ratios necessary to provide satisfactory stereophonic reception using the pilot-tone system. As additional information becomes available these figures can be amended if necessary to provide a sound basis for a Recommendation.

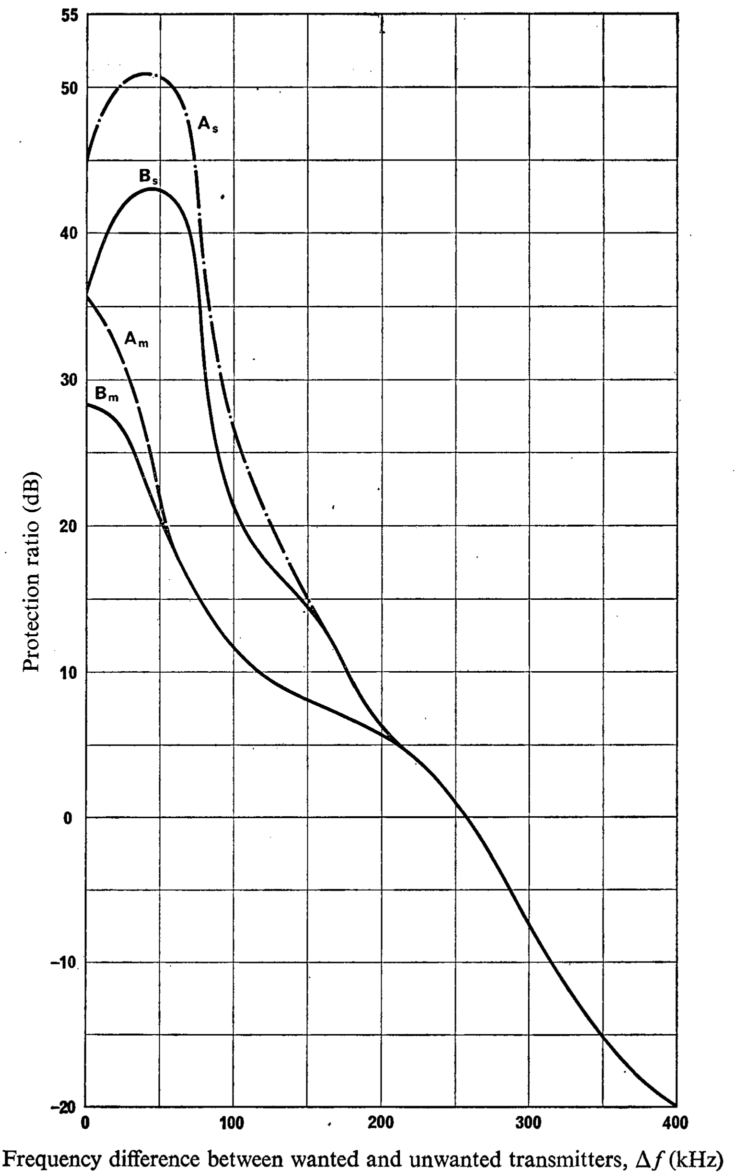

FIGURE 1

Protection ratios required by VHF broadcasting services at frequencies between 87·5 MHz and 108 MHz using a maximum frequency deviation of ± 75 kHz

Curve A_s : stereophonic broadcasting—steady interference
Curve B_s : stereophonic broadcasting—tropospheric interference (99% of the time)
Curve A_m: monophonic broadcasting—steady interference
Curve B_m: monophonic broadcasting—tropospheric interference (99% of the time)

Note. — Curves A_s and B_s assume the inclusion of a low pass filter in the receiver.
Curves A_m and B_m are reproduced, for reference, from Recommendation 412.

REPORT 463 *

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND PROGRAMMES IN FREQUENCY-MODULATION BROADCASTING

(Question 17-1/10)

(1970)

1. Introduction

The growing need for more programmes in almost all parts of the world makes it desirable to examine the present broadcasting standards to determine if changes are possible to provide a better utilization of the available frequency bands. The frequency-modulation service uses a large bandwidth to provide a programme service of exceptional quality. However, it has been found that some additional broadcasting services can be added without significant deterioration of the programme quality. This is an important consideration when the need for additional broadcasting services might make a reconsideration of the standards a necessity.

The analysis of supplementary sub-carrier operation in Doc. X/43 (U.S.A.), 1966–1969, shows that the use of a frequency-modulation sub-carrier provides the best signal-to-noise ratio for a given sub-carrier amplitude. Although the theoretical analysis of crosstalk is omitted, qualitative analysis (which is borne out by experience with sub-carrier operation) indicates that the system of modulation with the best signal-to-noise ratio also has the least crosstalk when other system parameters are the same.

Although the choice of the lowest possible sub-carrier frequency will provide the best signal-to-noise ratio in the supplementary sub-carrier channel, the sub-carrier frequency should be high enough to prevent audible beats. The use of a still higher sub-carrier frequency reduces the probability of crosstalk but unnecessarily reduces the signal-to-noise ratio.

2. Requirements for monitoring and test instruments

The basic purpose of the supplementary sub-carrier monitoring instruments are:

- to provide equipment for use in the routine operation and adjustment of the broadcasting station in its day-to-day operations;
- to provide the instrumentation necessary to test and prove the integrity of the transmitting system.

In keeping with the above requirements, the following parameters become subjects of interest:

- the degree of modulation of the main carrier by the sub-carrier;
- centre frequency of the sub-carrier;
- sub-carrier modulation;
- audio parameters of the modulated sub-carrier channel;
- crosstalk and noise;
- distortion and frequency response.

A further discussion of these parameters is contained in Doc. X/10 (U.S.A.), 1966–1969.

* This Report, which was adopted unanimously, has been brought to the attention of Study Group 1.

3. **Systems using one or more supplementary sub-carriers**

3.1 An FM-FM system using a compressor/expander in the *S* channel is described in Report 300-2.

3.2 An FM-FM system is described in Doc. X/44 (U.S.A.), 1966–1969. In this instance, the frequency of the sub-carrier was 67 kHz with a maximum deviation of the main carrier by the sub-carrier of ± 7·5 kHz during stereophonic broadcasting and a maximum deviation of the main carrier by the sub-carrier of ± 11·25 kHz during monophonic broadcasting. The maximum audio frequency of the supplementary channel is restricted to 6 kHz.

3.3 Doc. X/158 (U.S.A.), 1966–1969, gives the results of tests showing that it is possible to transmit simultaneously a main channel programme and a second programme using a supplementary sub-carrier. The frequency response is as good and the distortion as low as for the supplementary sub-channel as for the main channel. A sub-carrier frequency of 58 kHz was used. The deviation of the main carrier by the sub-carrier was ± 15 kHz and the deviation of the sub-carrier ± 12 kHz. The crosstalk figures were —70 dB or better for the main channel and about —50 dB for the sub-channel.

A system for the transmission of four supplementary sound programmes in frequency-modulation broadcasting is described in Doc. X/37 (U.S.A.), 1966–1969. In this instance four sub-carriers with frequencies of 70·75 kHz, 55·25 kHz, 39·75 kHz and 24·25 kHz are used. The maximum deviation of the main carrier by all four sub-carriers simultaneously is 22·5 kHz. The maximum audio-frequency of each sub-carrier is 3 kHz.

A similar FM-FM system providing two supplementary programmes is described in Doc. X/154 (Sweden), 1966–1969. The first sub-carrier has a frequency of 33·3 kHz and carries the second programme as described in Report 300-2. A third programme is carried on a second sub-carrier having a frequency of 66·6 MHz. This second sub-carrier, which has a deviation of ± 8 kHz, determines the deviation of the main carrier which is ± 3 kHz. The audio-frequency range is 40–5000 Hz. The system includes a compressor/expander with the same characteristics as mentioned in § 3.1. The crosstalk figures are better than —70 dB for the first and second channels and better than —60 dB for the third channel (when modulated at 100% in the third channel, and at 30% in the others, the crosstalk figure was better than —45 dB).

3.4 A frequency division multiplex broadcasting system is described in the first five pages of Doc. X/66 (U.S.S.R.), 1966–1969. This system uses a single-sideband type of modulation of the sub-carrier and a pilot tone of 20·8 kHz.

In one of the experiments, four channels are provided, the first two having audio frequencies up to 15 kHz, the third channel up to 10 kHz and the fourth (speech channel) up to 6 kHz.

Results are also given for an existing system of two-channel transmission which has a main (first) channel and a second channel using a sub-carrier frequency of 31·25 kHz using ordinary radio broadcasting receivers equipped with decoders for both channels.

4. **Use of supplementary sub-carriers for automatic receiver tuning**

An automatic receiver tuning device would be particularly useful in car radios when frequent retuning is required. Preliminary experiments have been reported in Doc. X/156 (Sweden), 1966–1969, whereby supplementary sub-carriers were employed to retune automatically car radios when passing from the service area of one transmitter to another.

REPORT 464 *

FREQUENCY-MODULATION BROADCASTING IN BAND 8 (VHF)

Polarization of emissions

(Question 19/10)

(1970)

1. Introduction

In band 8, field strength as well as quality of reception may differ according to whether the plane of polarization is horizontal or vertical. Moreover, these differences may be greatly influenced by terrain irregularities in the propagation path.

2. Comparison between the two types of polarization

Tests on the influence of the plane of polarization on both field strength and reception quality were carried out in the Federal Republic of Germany (Doc. X/141, 1966–1969) using a 1 kW transmitter at 97 MHz on the 392 m high Bielstein mountain near Detmold. The receiving antenna was a 4-element Yagi with a gain of 5·3 dB. The horizontal and vertical radiation diagrams of the transmitting antenna showed sufficient similarity. The signal in band 8 (VHF) was measured with a field-strength meter. The emission was modulated with sine-squared pulses. The audio-frequency output of the receiver was displayed on an oscilloscope, making it possible to observe the multipath propagation effects.

The majority of the receiving points were situated in hilly and wooded regions. These had been selected in such a way that reception was only possible by means of diffraction. Only in a small number of cases were the transmitting and the receiving antennae in line-of-sight.

Measurements were made at a total of 86 locations and the results obtained at 73 of these locations were useful. At 51 locations, reception was only possible by diffraction. The field-strength measurements and multipath effects are shown in Fig. 1.

The field strength values obtained with horizontal polarization exceeded those obtained with vertical polarization by 5 dB, with a standard deviation of ± 5·2 dB.

With horizontally polarized transmissions, practically no reflections were recorded. For vertically polarized transmissions, reflections were observed at 36 of the 51 locations selected.

3. Dual polarization

Doc. X/36 (U.S.A.), 1966–1969, includes data on field-strength measurements using dual polarization with,

— horizontally polarized V-type antenna with 10 kW e.r.p.;

— ring-type antenna transmitting horizontally polarized waves with 10 kW e.r.p.;

* This Report was adopted unanimously.

— the same ring-type antenna tilted at 45° and radiating 20 kW e.r.p.;
— ring-type antenna mounted horizontally with a separate vertical dipole for transmitting vertically polarized waves each at 10 kW e.r.p.;
— measurements were made at a frequency of 98 MHz.

Information is also included on the circularly polarized antenna being developed for use with frequency-modulation broadcast stations in the United States of America (Doc. X/40 (U.S.A.) 1963–1966).

Observations using a portable receiver and an automobile receiver, both equipped with vertical whip antennae, indicated that a more uniform coverage was achieved by the use of a dual polarized transmitting antenna.

The data indicates that the horizontal field was approximately 3 dB greater from the ring type antenna than from the V-type. Vertically polarized fields measured from the ring-type antenna averaged less than from the V-type antenna. Tilting the ring-type antenna was not an efficient method of obtaining dual polarization.

4. Receiving antenna

In Doc. X/156 (Sweden), 1966–1969, it is reported that a large improvement in reception in cars may be obtained by replacing the conventional whip antenna by a ferrite antenna in a vertical position. The ferrite antenna was 350 mm long, with a diameter of 30 mm. By tuning this antenna the efficiency, with a low-noise receiver, was about the same as that of a vertical half-wave dipole.

In the same document, it is also reported that reception in cars can be further improved by using diversity reception. The method used was to switch between two antennae by a special electronic device, controlled by amplitude variation of a sub-carrier when severe multipath propagation distortion effects were met.

5. Conclusions

5.1 Doc. X/141 (Federal Republic of Germany), 1966-1969, indicates that, under certain conditions, higher field strengths and reception of better quality are achieved using horizontally polarized emissions.

5.2 Docs. X/40 (U.S.A.), 1963-1966 and X/36 (U.S.A.), 1966-1969, indicate that, for reception by portable and automobile receivers, both using vertical antennae, more uniform coverage is provided by dually polarized transmissions.

5.3 Doc. X/156 (Sweden), 1966-1969, indicates that a special ferrite antenna mounted on an automobile successfully replaced the vertical whip antenna in the case of transmissions with horizontal polarization.

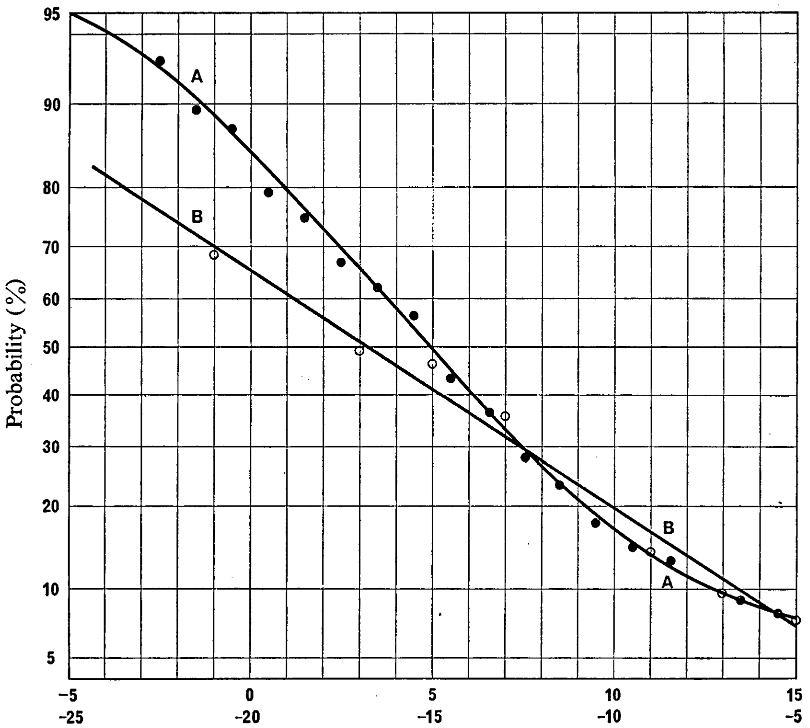

FIGURE 1

Probability that the ratio of the field strengths exceeds a given value at a given percentage of locations

Curve A: For horizontal and vertical polarization of emissions
Curve B: For direct and reflected radiation with vertical polarization

SECTION 10C: SOUND BROADCASTING IN THE TROPICAL ZONE

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 48

CHOICE OF FREQUENCY TO AVOID INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING IN THE TROPICAL ZONE

(Question 27/10)

The C.C.I.R., (1951)

CONSIDERING

(a) that an audible interfering beat note may occur between two adjacent broadcasting carriers in the shared bands, irrespective of the position of the frequencies used by other services;

(b) that the minimum tolerable ratio of the wanted-to-unwanted signal field-strengths depends primarily upon the frequency separation between the carrier waves;

(c) that it is extremely important that all stations operate with the best frequency stability obtainable;

(d) that transmitters of poor frequency stability may be capable of causing harmful interference to broadcasting in the Tropical Zone when operated in the shared bands;

(e) that mobile stations, due to their lower frequency stability and variable location, are likely to cause more interference than fixed stations to broadcasting in the Tropical Zone when operated within the shared bands, particularly when using class of emission A3;

RECOMMENDS

1. that it is not necessary for frequencies of other services sharing frequency bands with broadcasting in the Tropical Zone to be assigned only midway between the broadcasting frequencies. When, however, mid-spaced frequencies are not assigned it is desirable that the same frequencies should be assigned for other services as for broadcasting. The use of frequencies midway between broadcasting station carriers would have the advantage that less stringent tolerances would be required to maintain the required degree of protection than would be the case when frequencies of other services are assigned indiscriminately between adjacent broadcasting frequencies;

2. that Administrations should attempt to improve, as soon as possible, the frequency stability of fixed stations and, more generally, of all stations operating in the shared bands to the values specified in App. 3, Col. 3, of the Radio Regulations. Administrations should arrange for transmitters which do not meet this requirement to operate only on frequencies outside the shared bands, unless there is little possibility of interference to broadcasting services in the Tropical Zone;

3. that, wherever possible, Administrations should avoid the operation of mobile stations in the Tropical Zone within the bands shared with broadcasting, particularly as regards the use of class of emission A3 by such mobile stations.

RECOMMENDATION 49

CHOICE OF SITE OF STATIONS AND TYPE OF ANTENNA TO AVOID INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING IN THE TROPICAL ZONE

(Question 27/10)

The C.C.I.R., (1951)

CONSIDERING

(a) the provisions of Art. 14, No. 695, of the Radio Regulations;

(b) that all possible sources of interference to broadcasting should be minimized;

RECOMMENDS

1. that Administrations should make every effort to comply, as soon as possible, with the Regulations with regard to the siting of stations and the use of directional antennae when the nature of the service permits;

2. that Administrations should take steps to ensure that all interference to broadcasting and other radio services in the Tropical Zone produced by radiation, such as key-clicks, sideband spread, etc., be kept to a minimum;

3. that the broadcasting services in the Tropical Zone should, for their part, reciprocally take similar precautions to facilitate the operation of other services working in other zones in the shared bands.

RECOMMENDATION 139

DESIGN OF TRANSMITTING ANTENNAE FOR BROADCASTING IN THE TROPICAL ZONE

The C.C.I.R., (1953)

CONSIDERING

(a) that it is desirable to use transmitting antennae for broadcasting in the Tropical Zone that cause a minimum of interference outside the service area;

(b) that the antennae should be economical in design and simple in operation;

(c) that Report 301-2 gives the principles on which antennae for broadcasting in the Tropical Zone should be designed and constructed;

(d) that it is desirable to obtain as many operational data as possible on broadcasting in the Tropical Zone using antennae designed on these principles;

RECOMMENDS

1. that Administrations and organizations operating broadcasting services in the Tropical Zone should use antenna systems so designed that:

— the power radiated is as large as possible at the high angles of elevation required for the needs of the service area,

— a sufficient value of radiation should be maintained at angles of elevation necessary to serve the fringe of the service area,

— the power radiated at angles of elevation lower than those used to serve the fringe of the service area is as low as possible;

2. that Administrations and organizations should forward to the C.C.I.R. reports on the operation of such antennae so that an addendum can be issued to Report 301-2 giving practical operational data concerning these antennae. The data and information should be forwarded in the following form:

— type of antenna system used and its physical dimensions in relation to the frequency of operation;

— electrical characteristics—polar diagram in the vertical and the horizontal planes;

— power radiated by the antenna;

— siting of the antenna with respect to the geographical configuration of the area to be served and the orientation of the antenna with respect to North;

— hourly averages of field strength measured, whenever practicable, every 100 or 200 km, up to a maximum distance of 2000 km in all directions;

— fading characteristics of the received signal;

— influence, if any, of the orientation of the antenna with respect to the magnetic meridian;

— ground conductivity in the vicinity of the antenna system;

— any other information considered useful in respect of this Recommendation.

RECOMMENDATION 140

DESIGN OF RECEIVING ANTENNAE FOR BROADCASTING IN THE TROPICAL ZONE

The C.C.I.R., (1953)

CONSIDERING

(a) that only simple antennae are practicable for the great majority of domestic broadcast listeners in the Tropical Zone;

(b) that the antenna has to be both cheap and simple to install and that it has to be used on a number of frequencies with fields at varying angles of incidence;

RECOMMENDS

1. that the directivity of receiving antennae cannot be relied upon to improve the signal-to-noise ratio;

2. that it appears reasonable to assume that the antenna of the average listener cannot be better than that given in the Report of the Geneva Planning Committee, 1948, which consisted of an " L " type antenna with horizontal and vertical limbs, each 4·90 m (16 feet) long.

RECOMMENDATION 214

LIMITATION OF THE POWER OF TRANSMITTERS IN THE TROPICAL ZONE TO AVOID INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING IN THE TROPICAL ZONE

(Question 27/10)

The C.C.I.R., (1951 - 1956)

CONSIDERING

(a) that the power of transmitters for radio services in the Tropical Zone, operating within the bands shared with tropical broadcasting (Art. 7, No. 425 of the Radio Regulations), should be determined to ensure full protection to broadcasting in the Tropical Zone;

(b) that it is preferable to exploit the possibilities of " time sharing " between broadcasting services in the Tropical Zone and radiotelegraph services operating within the shared bands;

(c) that, at sunspot minimum, when certain frequencies become useless for broadcasting in the Tropical Zone, such frequencies could be used by other services;

(d) that Recommendation 215 recommends provisional power limitations for broadcasting stations in the Tropical Zone;

(e) that the maximum power of radiotelegraph stations can best be determined in the light of the permissible " repetition distance " (geographical sharing, see Provisional Frequency Board (P.F.B.) Doc. 712, 14 February, 1950);

(f) that the protection ratio to be considered in the determination of the " repetition distance " will be that set forth in Recommendation 216 read in conjunction with Report 302;

(g) that the factors governing the limitation of power for class of emission A3 by services other than broadcasting within the shared bands are similar to those for radiotelegraphy;

RECOMMENDS

1. that, for the particular cases not involving simultaneous operation of broadcasting and other services, no limitations should be imposed on the power of radiotelegraph stations operating within the shared bands other than those necessary to comply with the provisions of Section I, Art. 14 of the Radio Regulations;

2. that, for the general case involving the simultaneous operation of broadcasting and radiotelegraph services within the shared bands, the limitation to be imposed on the power of radiotelegraph stations in the Tropical Zone should be only that required to provide adequate protection for the broadcasting services;

3. that the limitations for fixed service stations in the Tropical Zone, employing class of emission A3 and operating within the shared bands, should be similar to those for radiotelegraph stations operating under like conditions.

RECOMMENDATION 215 *

MAXIMUM POWER FOR SHORT-DISTANCE BROADCASTING IN BAND 7 (HF) IN THE TROPICAL ZONE **

(Question 27/10, Study Programme 27A/10, Recommendation 214)

The C.C.I.R., (1956)

CONSIDERING

(a) that the prolonged observations and studies which have been carried out confirm the existence of high noise levels in the Tropical Zone;

(b) that good quality service presupposes the maintenance of a satisfactory value of signal-to-noise ratio in the entire service zone, which the provisional power limits mentioned in Recommendation 84 cannot ensure, with appropriate coverage up to 800 km;

(c) that the high value of noise level observed in tropical regions during certain hours of the day and certain periods of the year, together with the need for signal-to-noise ratios such as to ensure a satisfactory service for practically all listeners within the specified service area, tends to suggest the use of a high transmitter-power for broadcasting services in the Tropical Zone. It is therefore advisable, when evaluating the powers to be used, to assume reasonable values for the average noise level and signal-to-noise ratio to reach practical values of transmitter powers, ensuring acceptable conditions of reception for a suitable percentage of transmission time at the limit of the service area;

(d) that, when the service zone is limited to 400 km, vertical incidence antennae may be used effectively to concentrate the energy in the service zone and to reduce radiation beyond this zone;

(e) that, for greater distances, it appears necessary to use types of antenna with low gain, such as a simple dipole, to obtain the required field strength at a distance of 800 km. Nevertheless, this type of antenna radiates at low angles of elevation and may give rise to interference at great distances;

(f) that it is advisable to make a judicious choice of transmitting frequencies which, for a broadcasting programme in the Tropical Zone may be located in the shared bands the upper limit of which is 5060 kHz and in band 7 (HF) at frequencies above 5060 kHz;

RECOMMENDS

1. that the upper power limit for the unmodulated carrier wave of short-distance high-frequency broadcasting transmitters employing double-sideband emission, operating in the Tropical Zone should be determined as follows:

1.1 for a service area limited to 400 km, the nominal power of the transmitter should not exceed 10 kW;

1.2 for a service area limited to 800 km, the nominal power of the transmitter should not exceed 30 kW;
the powers mentioned in §§ 1.1 and 1.2 are for frequencies below 5060 kHz used in broadcasting in the Tropical Zone for such ranges;

* France, the United Kingdom (for § 1.3), the Overseas Territories of the French Republic, Turkey (for § 1.3) and the Republic of South Africa reserved their opinions on this Recommendation.

** As defined in the Annex to Study Programme 27A/10 for this service.

1.3 for frequencies above 5060 kHz, where broadcasting services in the Tropical Zone use the same frequency bands as the HF broadcasting services, the same power limit as recommended by the Mexico City Conference, 1949, shall apply;

2. that, within the above limits, Administrations should use, as far as possible, lower powers, if these will ensure satisfactory service throughout the reception area;

3. that the frequency used should always be as near as possible to the optimum working frequency (provided that the frequency employed is within one of the permissible broadcasting bands), to provide as good a received signal-to-noise ratio as possible;

4. that, in conformity with the provisions of Recommendation 139, and to make the best possible use of the frequency bands which have been allocated, Administrations should use appropriate antennae, so that radiations at low angles be reduced to a minimum, to avoid all harmful interference outside the service zone.

RECOMMENDATION 216

MINIMUM PERMISSIBLE PROTECTION RATIO TO AVOID INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING IN THE TROPICAL ZONE

(Report 302, Question 27/10)

The C.C.I.R., (1951 – 1953 – 1956)

CONSIDERING

(a) that it is necessary to establish, as soon as possible, a value for the minimum permissible protection ratio for broadcasting within the shared bands in the Tropical Zone;

(b) that the operation of broadcasting transmitters with 10 kHz separation makes it difficult to measure the protection ratio with a receiver having an audio-frequency cut-off in excess of 5 kHz;

(c) that, in the absence of sufficient information concerning noise values in various parts of the Tropical Zone, it is difficult to state a value of minimum field strength to which the minimum permissible protection ratio should be maintained; however, this minimum field strength should provide satisfactory reception at the limit of the broadcast station service area, as provided by Art. 7, No. 423, of the Radio Regulations;

RECOMMENDS

1. that, for the present and wherever practicable in the Tropical Zone, the ratio of median wanted broadcasting carrier to median unwanted carrier shall be 40 dB, to provide a signal-to-interference ratio of not less than 23 dB for 90% of the hours and 90% of the days (ref.: Doc. 635, § 13, Mexico City, 1948/49 and Doc. 43, Washington, 1950, which refers in particular to the effect of long and short term fading);

2. that the protection ratio thus defined should be measured at the output of a receiver provided with a filter having an audio-frequency cut-off of 5·0 kHz;

Note. — Practical consideration of the frequency separation of adjacent channels requires the use of an audio-frequency cut-off of 5 kHz in the measurement in preference to 6·4 kHz, appropriate corrections being applied, if considered necessary, to correspond to an audio-frequency cut-off of 6·4 kHz.

3. that, for the present, the protection ratio, as defined in § 1, should be maintained throughout the broadcast service area in the Tropical Zone to a minimum field strength of 200 μV/m or any lower value consistent with satisfactory reception;

4. that the conditions of operation required for broadcasting in the Tropical Zone should be compatible with the protection ratio required for other services outside the Tropical Zone, in accordance with Art. 3, No. 117, § 5, of the Radio Regulations.

RECOMMENDATION 415

PERFORMANCE SPECIFICATIONS FOR LOW-COST SOUND-BROADCASTING RECEIVERS

The C.C.I.R., (1963)

CONSIDERING

(a) Recommendation No. 7 of the Administrative Radio Conference, Geneva, 1959;

(b) that the advantages of broadcasting should be made more easily available to the populations of the countries where, at present, the density of receivers is particularly low due to economic, geographical or technical reasons;

(c) that to this end, it is desirable that efficient broadcasting receivers should be available at prices low enough to secure their wide distribution in those countries;

(d) that general agreement on the performance of suitable broadcasting receivers would prove most useful to radio receiver manufacturers by assisting them to produce suitable receivers, having an agreed adequate standard of performance, at the lowest possible cost;

UNANIMOUSLY RECOMMENDS

that the minimum performance specifications, contained in the Annex, be used to assist in the design and development of low-cost sound broadcasting receivers suitable for production in large quantities.

ANNEX

These specifications apply to the following types of receivers:

Type A: a low sensitivity receiver for operation in band 6 (MF),

Type B: a combined receiver for operation in bands 6 (MF) and 7 (HF),

Type C: a medium sensitivity frequency-modulation receiver for operation in band 8 (VHF).

1. General

1.1 Each of the three types of receiver should be available for either mains or battery operation. For battery operation, all three types of receiver should be fully transistorized to ensure economy of power consumption. For mains operation, either valves or transistors may be used, consideration of cost being the guiding factor.

1.2 For battery-operated receivers, the minimum performance specifications listed in this Recommendation should be achieved for the nominal battery voltage less 30% as specified in the relevant IEC publication.

1.3 The methods of measurement employed should be those recommended in the relevant IEC publications for amplitude-modulation receivers and frequency-modulation receivers (see Recommendation 237).

1.4 The receivers should be simple, robust and well protected against dust. Those intended for use in regions of high temperature and humidity should be treated so that they can be used under the climatic conditions laid down by the Administration concerned. The appropriate tests required by the Administration procuring such receivers should comply with the relevant IEC publications.

1.5 If national regulations prescribe methods of measurement or tests differing from the standard IEC methods, Administrations will, where necessary, draw attention to this.

2. Specification for Type A receivers

2.1	Frequency coverage	525–1605 kHz
2.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	5 mV/m (with a built-in antenna with facilities for using an external antenna).
2.3	Signal/noise ratio for input as under § 2.2	20 dB (mains-operated tube receivers) 26 dB (transistor receivers)
2.4	Power output, for less than 10% distortion	not less than 0·1 W
2.5	Overall selectivity	
	at — 6 dB points	passband not less than ± 3 kHz
	at —20 dB points	passband not greater than ± 10 kHz
2.6	Image, intermediate frequency and spurious response ratio	not less than 30 dB
2.7	Overall fidelity including acoustic response of loudspeaker, or,	250–3150 Hz, within 18 dB limits
	Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	100–4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)

3. Specification for Type B receiver (the two types differing only in frequency range)

3.1	Frequency coverage	B1: 0·525–1·605; 2·3–16 MHz B2: 0·525–1·605; 2·3–21·75 MHz The receiver shall be provided with adequate mechanical and/or electrical means for easy tuning

3.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	not worse than 150 μV
3.3	Signal-to-noise ratio, for input as under § 3.2	20 dB (mains-operated tube receivers) 26 dB (transistor receivers)
3.4	Power output, for less than 10% distortion	not less than 0·1 W
3.5	Overall selectivity	
	at — 6 dB points	passband not less than ± 3 kHz
	at —20 dB points	passband not greater than ± 10 kHz
	at —40 dB points	passband not greater than ± 20 kHz
3.6	Image, intermediate frequency and spurious response ratio	MF—not less than 30 dB
	Intermediate frequency and spurious response ratio	HF—not less than 12 dB
	Image response ratio	HF—not less than 5 dB
3.7	Overall fidelity including acoustic response of loudspeaker, or,	250–3150 Hz within 18 dB limits
	Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	100–4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
3.8	A.g.c. performance: change in output when the input is reduced by 30 dB from 0·1 V	not greater than 10 dB
3.9	Frequency stability	must be such that the receiver does not require frequent retuning

4. Specification for Type C receivers

4.1	Frequency coverage	87·5–108 MHz
4.2	Signal-to-noise ratio	30 dB
4.3	Sensitivity (noise limited)	—75 dB rel. 1 mW (at a signal-to-noise ratio of 30 dB and 50 mW output power)
4.4	Intermediate frequency	10·7 MHz
4.5	Amplitude-modulation suppression ratio	20 dB
4.6	Power output	not less than 0·1 W
4.7	Overall selectivity	—30 dB at ± 300 kHz
4.8	Overall fidelity including acoustic response of loudspeaker, or,	200–5000 Hz within 18 dB limits
	Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	100–5000 Hz within 6 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)

4.9 Radiation	The local oscillator radiation should be less than the limits specified by C.I.S.P.R. However, where national regulations exist, the radiation should be less than the limits specified therein.
4.10 Distortion	The distortion should be less than 5% for a frequency deviation varying between ± 15 kHz and ± 75 kHz with a modulation frequency of 400 Hz and an output power of 50 mW
4.11 Frequency stability	Must be such that the receiver does not require frequent retuning.

RECOMMENDATION 416

PERFORMANCE SPECIFICATIONS FOR LOW-COST SOUND-BROADCASTING RECEIVERS FOR COMMUNITY LISTENING

The C.C.I.R., (1963)

CONSIDERING

(a) Recommendation No. 7 of the Administrative Radio Conference, Geneva, 1959;

(b) that community receivers provide the easiest method of making broadcasting available to the populations of those countries where, at present, the density of receivers is particularly low due to economic, geographical or technical reasons;

UNANIMOUSLY RECOMMENDS

that the minimum performance specifications, contained in the Annex, be used to assist in the design and development of low-cost community receivers.

ANNEX

1. General

1.1 The receivers should be simple, robust and well protected against dust. They should also be strong enough to withstand transport and handling by unskilled persons.

1.2 The pre-set tuning controls should be available only to authorized persons. The controls should be robust and include a channel selection switch, a fine tuning control to facilitate accurate tuning and compensate for any frequency drift during operation, and a volume control.

1.3 Each of the two types of receiver considered in §§ 2 and 3 should be available for either mains or battery operation. For battery operation, the receivers should be fully transistorized to ensure economy of power consumption. For mains operation, either valves or transistors may be used, consideration of cost being the guiding factor.

1.4 For battery-operated receivers, the minimum performance specifications listed in this Recommendation should be achieved for the nominal battery voltage less 30% as specified in the relevant IEC publication.

1.5 The methods of measurement employed should be those recommended in the relevant IEC publications for amplitude-modulation and frequency-modulation receivers (see Recommendation 237).

1.6 The receivers, which are intended for use in regions of high temperature and humidity, should be treated so that they can be used under the climatic conditions laid down by the Administration concerned. The appropriate tests required by the Administration procuring such receivers should comply with the relevant IEC publication.

1.7 If national regulations prescribe measuring methods or tests different from the standard IEC methods, the Administrations will, where necessary, draw attention to this.

2. Specification for a community receiver operating in bands 6 (MF) and 7 (HF)

(Two types, differing only in frequency range)

2.1 Frequency coverage (MHz) — *(a)* 0·525–1·605; 2·3–21·75
(b) 0·525–1·605; 2·3– 9.775

2.1.1 Receiver tuning may be fully bandspread on the broadcast bands appropriate to the requirements of any Administration or the receiver should be capable of being coarse pre-tuned to any spot frequency in:

— band 6 (MF) and

— each of the bands in band 7 (HF);

with the provision that a limited number of spot frequencies (e.g. three), selected from band 7 (HF) are made available for ready selection at any time, by the operator.

2.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	not worse than 150 μV
2.3	Signal/noise ratio for input as under § 2.2	26 dB
2.4	Power output for less than 10% distortion	not less than 900 mW (at nominal mains or battery voltage) and not less than 400 mW (at the nominal battery voltage less 30%)
2.5	Overall selectivity	
	at — 6 dB points	passband not less than ± 3 kHz
	at —20 dB points	passband not greater than ± 10 kHz
	at —40 dB points	passband not greater than ± 20 kHz
2.6	Image, intermediate frequency and spurious response ratio	MF—not less than 30 dB
	Intermediate frequency and spurious response ratio	HF—not less than 12 dB
	Image response ratio	not less than 10 dB (HF up to 10 MHz)
	Image response ratio	not less than 5 dB (HF up to 21·75 MHz)

2.7	Overall fidelity including acoustic response of loudspeaker, or,	250–3150 Hz within 18 dB limits
	Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be:	100–4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
2.8	A.g.c. performance: change in output when the input is reduced by 30 dB from 0·1 V	not greater than 10 dB
2.9	Frequency stability	must be such that the receiver does not require frequent retuning

3. Specification for a community receiver operating in band 8 (VHF)

3.1	Frequency coverage	87·5–108 MHz (provision must be made for one or more channels to be preselected)
3.2	Signal-to-noise ratio	30 dB
3.3	Sensitivity (noise limited)	—85 dB rel. 1 mW (at a signal-to-noise ratio of 30 dB and 50 mW output power)
3.4	Intermediate frequency	10·7 MHz
3.5	Amplitude-modulation suppression ratio	24 dB
3.6	Power output	Not less than 900 mW (at nominal mains or battery voltage) and not less than 400 mW (at the nominal battery voltage less 30%)
3.7	Overall selectivity	—30 dB at ± 300 kHz
3.8	Overall fidelity including acoustic response of loudspeaker, or,	200–5000 Hz within 18 dB limits
	Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	100–5000 Hz within 6 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
3.9	Radiation	The local oscillator radiation should be less than the limits specified by C.I.S.P.R. However, where national regulations exist, the radiation should be less than the limits specified therein
3.10	Distortion	The distortion should be less than 5% for a frequency deviation varying between ± 15 kHz and ± 75 kHz with a modulation frequency of 400 Hz and an output power of 50 mW
3.11	Frequency stability	Must be such that the receiver does not require frequent retuning.

REPORT 301-2 *

DESIGN OF TRANSMITTING ANTENNAE FOR BROADCASTING IN THE TROPICAL ZONE

(Question 29/10)

(1953 – 1956 – 1963 – 1966 – 1970)

This Report summarizes the information submitted to the C.C.I.R. in answer to the studies under Questions 70 and 29/10.

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, 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 locate 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 I). Angles of slew greater than about 15° 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, a central location is less important.

2. The transmitting antenna for broadcasting in the Tropical Zone 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 to reduce the low-angle radiation ** (see Annexes).

It is considered desirable that the C.C.I.R. should include the curves shown in the Annexes, or similar ones, in its antenna charts. ***

It is possible that the siting of the transmitting antenna used for broadcasting in the Tropical Zone with respect to the magnetic meridian has an influence on the field produced by reflection from the ionosphere. It is therefore requested that reference should be made to this point in answer to Question 28/10, dealing with propagation in the Tropical Zone.

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* This Report was adopted unanimously.

** P. Adorian and A. Dickenson, High-frequency broadcast transmission with vertical radiation. *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.

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.

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 average listener's antenna cannot be better than that given in the Report by the Geneva Planning Committee; this consists of an L-type antenna with horizontal and vertical limbs 16 feet in length (4·9 m).

4. Doc. 470 (United Kingdom), Warsaw, 1956, describes briefly the measurements carried out in Barbados of short-wave (decametric) broadcast transmissions from Trinidad (350 km) at 3 and 6 MHz and the attempts made to observe the field intensities of transmissions from Jamaica.

4.1 Consideration of the data indicates that a vertical incidence 4-element antenna, 1/4-wavelength above ground, will be useful for minimizing low-angle radiation beyond a service area limited to about 350 km and thus reducing 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.

4.2 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.

4.3 It is also desirable that, whilst communicating data on frequency requirements, Administrations should define the area for which the broadcast service is intended.

ANNEX I

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 $\lambda/2$ dipoles end to end, the rows being $\lambda/2$ 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

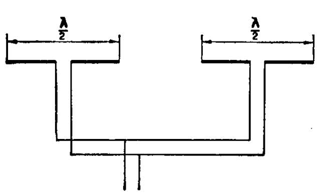
For the vertical radiated field to be a maximum, the optimum height of the dipoles above ground is $\lambda/4$ but the height is not critical. Figs. 1, 2 and 3 correspond to a height of $0{\cdot}2\ \lambda$ above ground, but each of the curves shown may be converted to apply to any height of *h* wavelengths above ground, by multiplying by:

$$\sin(2\pi h \cos\theta) \,/\, \sin(0{\cdot}4\,\pi \cos\theta)$$

4. Slewing

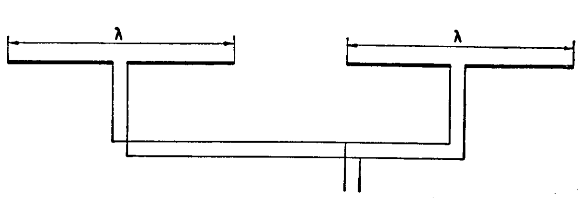
The diagrams shown in Figs. 1, 2 and 3 assume equal co-phasal currents in all the half-wave dipoles, and as may be seen, this results in a diagram suitable for a station situated in the centre of the service area.

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.

For an array with two dipoles in each row, the diagram will be modified by multiplying by:

$$\cos[(\pi/2)\sin\theta + \varphi/2] \,/\, \cos[(\pi/2)\sin\theta]$$

For an array with four dipoles in each row, the diagram will be modified by multiplying by:

$$\cos(\pi\sin\theta + \varphi/2) \,/\, \cos(\pi\sin\theta)$$

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:

arc sin (φ/π), for the array two dipoles wide,

arc sin $(\varphi/2\pi)$, 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 0·1 λ 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 $\lambda/2$ beyond the extremities of the array when viewed in plan.

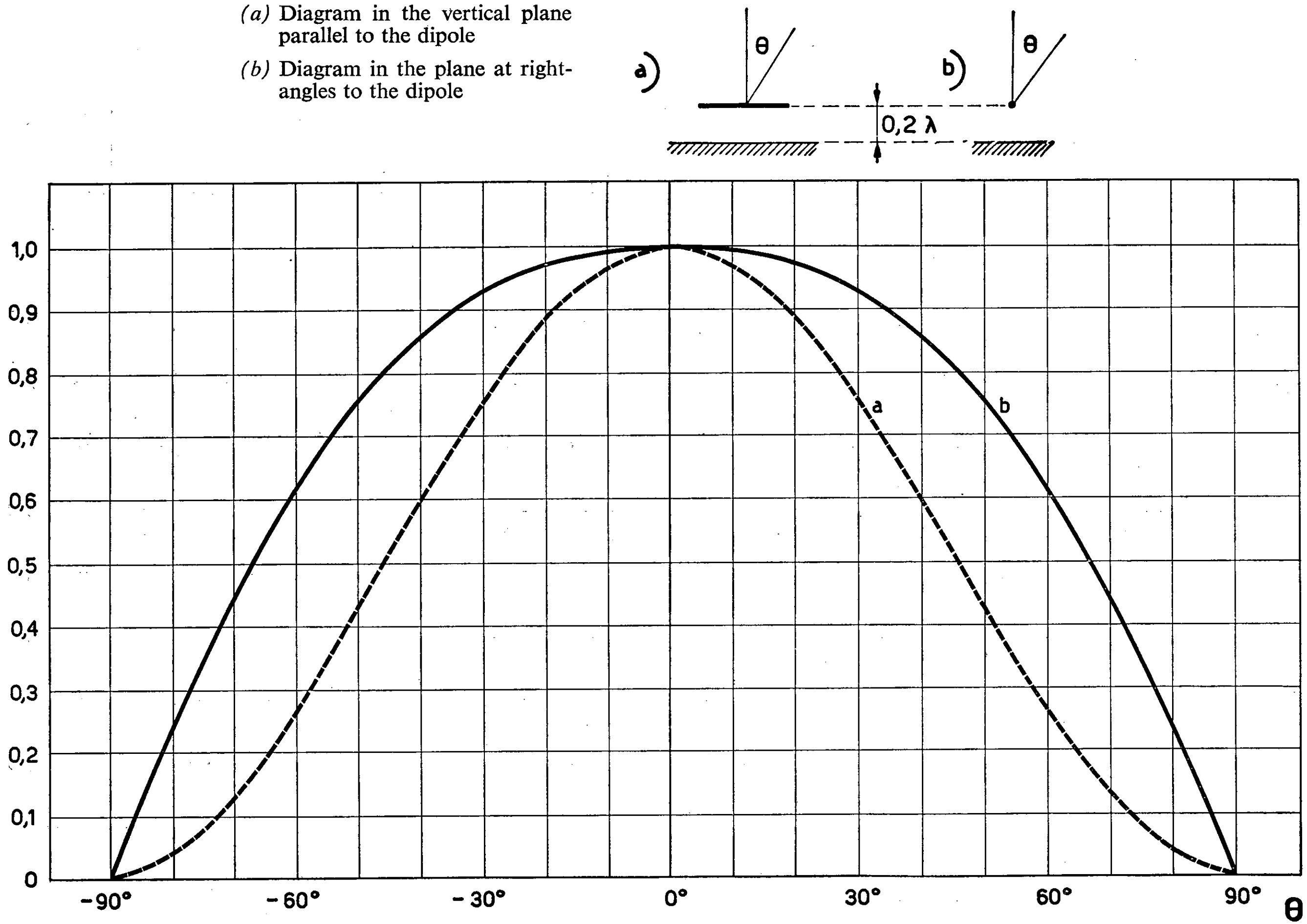


FIGURE 1

Diagram of a single λ/2 horizontal dipole

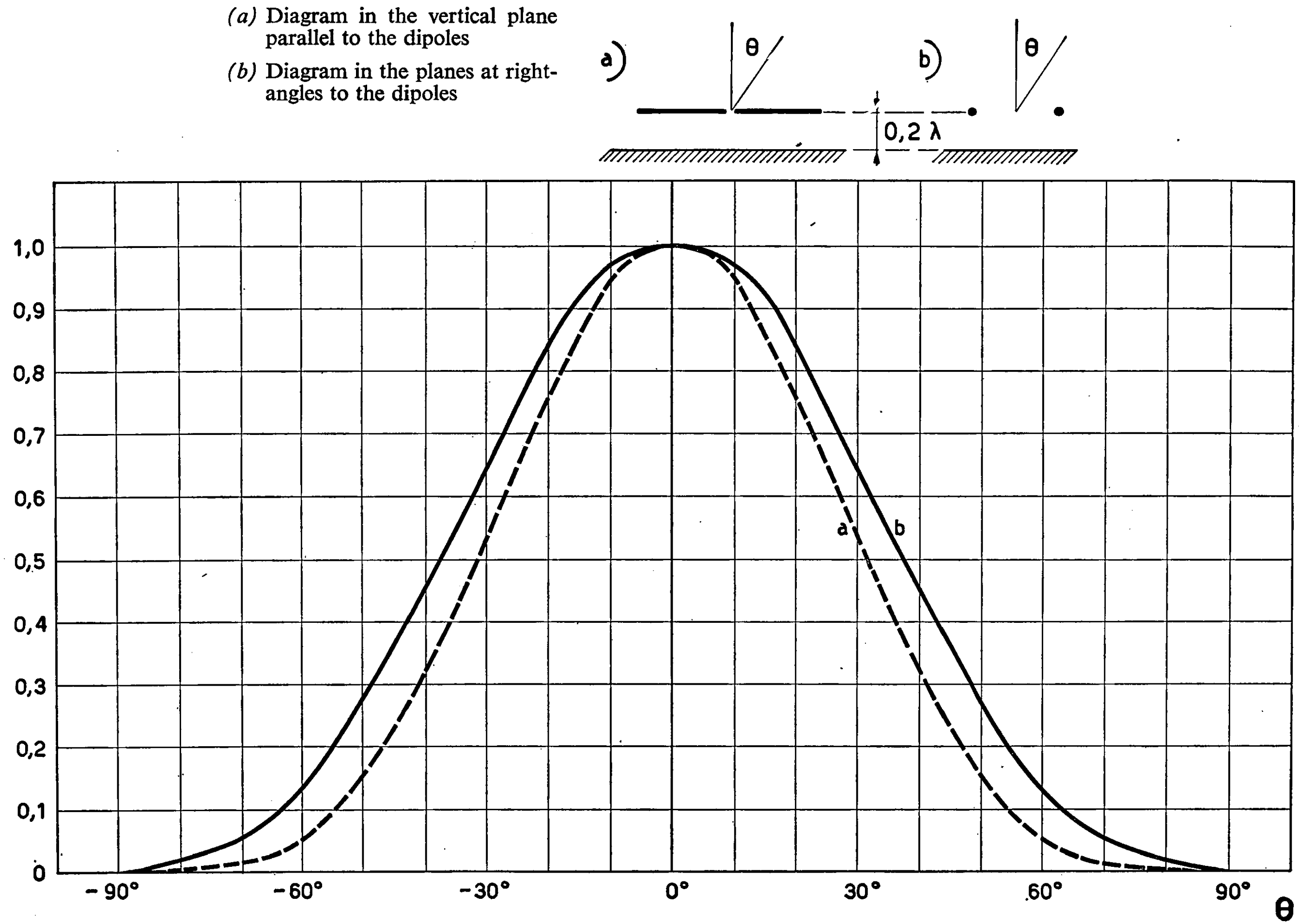


FIGURE 2

Diagram of an H2/2 array as shown

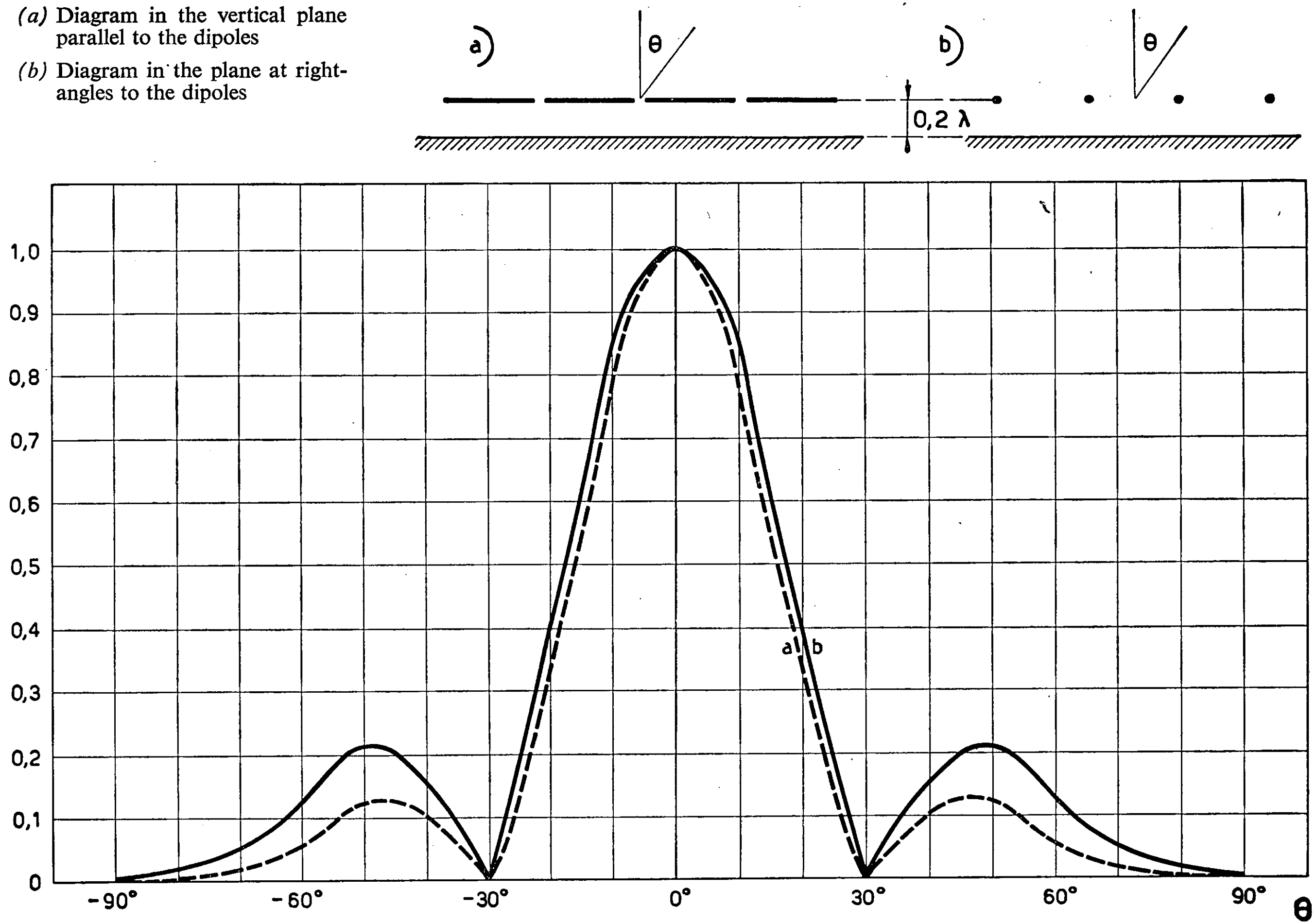


FIGURE 3

Diagram of an H4/4 array as shown

ANNEX II

HIGH-INCIDENCE ARRAY

1. Doc. XII/1 (Republic of South Africa), Bad Kreuznach, 1962, describes a high-incidence array which will give adequate high-frequency coverage over a circular area of up to 1000 km radius. Special attention has been given to the minimizing of low-angle radiation, to eliminate interference to other services outside the coverage area.

2. The array consists of four full-wave dipoles arranged in the form of a square and fed in such a manner that the currents in any two adjoining elements are in phase. The average height above ground is 0·15 λ, but this does not seem to be critical. Fig. 4 is a sketch of the array showing the method of feeding. The radiating elements are built up of four wire cages, resulting in an impedance of 2200 Ω each which, when paralleled at the centre, give a good match to a 550 Ω feeder. A quarter-wave matching stub is included.

Fig. 5 shows the field radiated at an angle of elevation of 10° by a dipole (h = 0·4 λ) and the high-incidence array.

Fig. 6 shows the distribution of the field of the high-incidence array in two vertical planes:

— diagonal to the square (Fig. 6*a*),

— parallel to a side of the square (Fig. 6*b*),

representing the directions of maximum and minimum radiation respectively.

Fig. 7 is a power distribution diagram of the high-incidence array, the value of 100% being obtained by integrating the power distribution diagram and equating

$$\int\int E^2 \, d\theta \, d\varphi = \eta P$$

The gain of the array, relative to an isotropic radiator, is 8 dB.

3. It is found that the low-angle radiation of the array is less than that of a dipole (h = 0·4 λ) in all horizontal directions (see Fig. 5). At any angles of elevation below 30°, the radiation from the high-incidence array is 16 dB less than the maximum radiated by the dipole at that elevation.

The high-angle radiation of the array is greater than that of the dipole in the broadside direction at elevation angles between 50° and 75°, and greater than that of the dipole in the end-on direction at elevation angles between 25° and 75°, representing improved signal strength at distances between 100 and 400 km, and 100 and 1000 km in the respective directions.

The measurements of low-angle radiation (less than 30°), were made on a scale model of the array and the measurements of high-angle radiation were made in the field on the actual array.

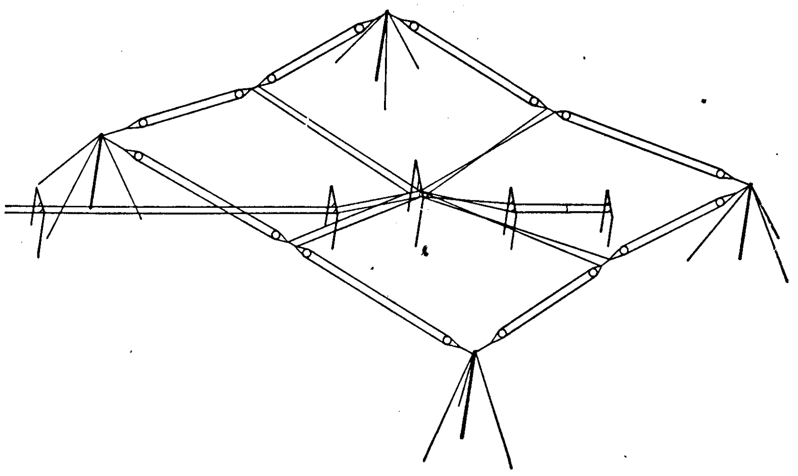


FIGURE 4

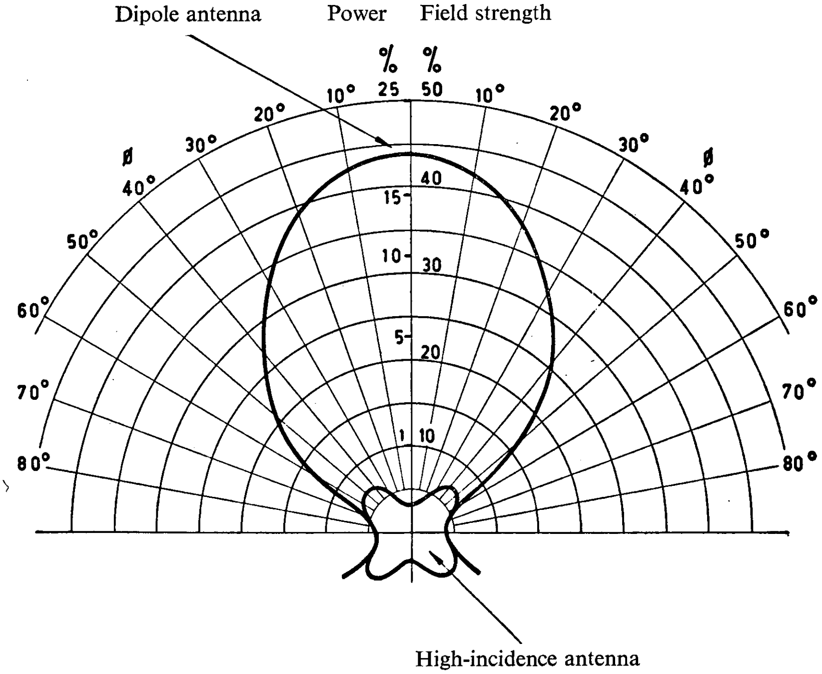


FIGURE 5

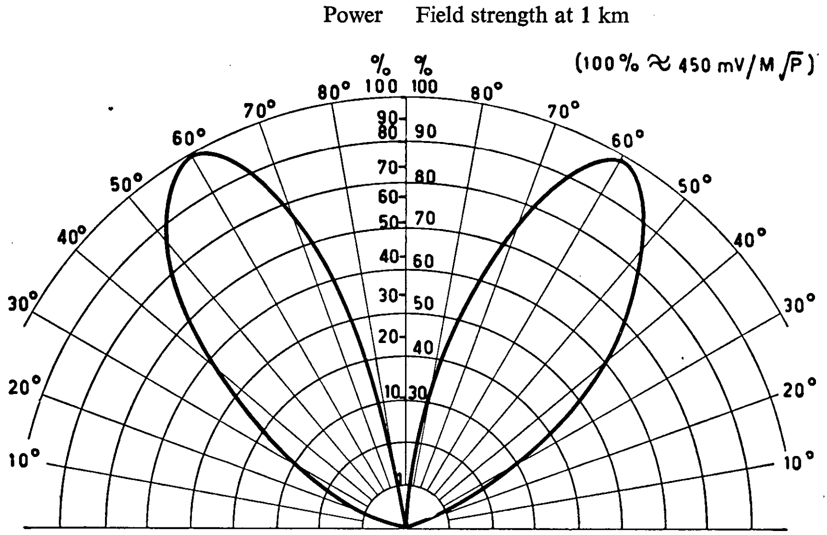


FIGURE *6a (diagonal to the square)*

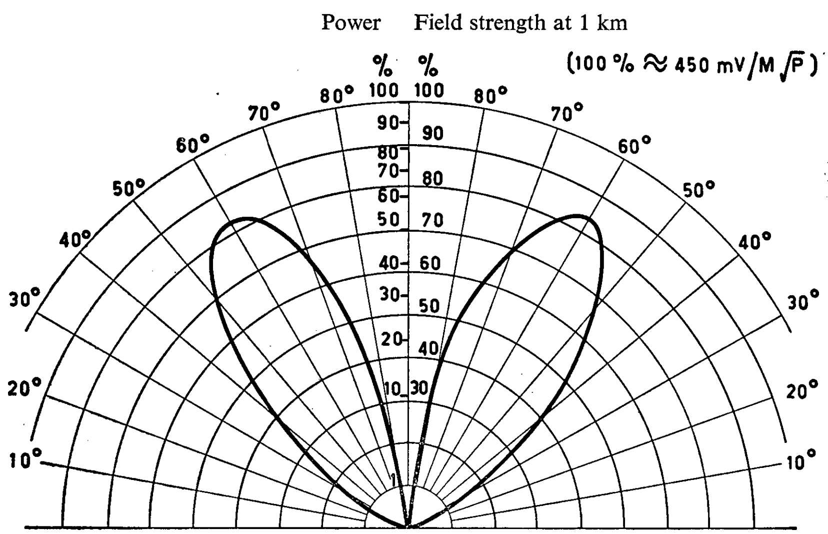


FIGURE *6b (parallel to one side)*

FIGURE 6

Measured polar diagrams for a high-incidence antenna

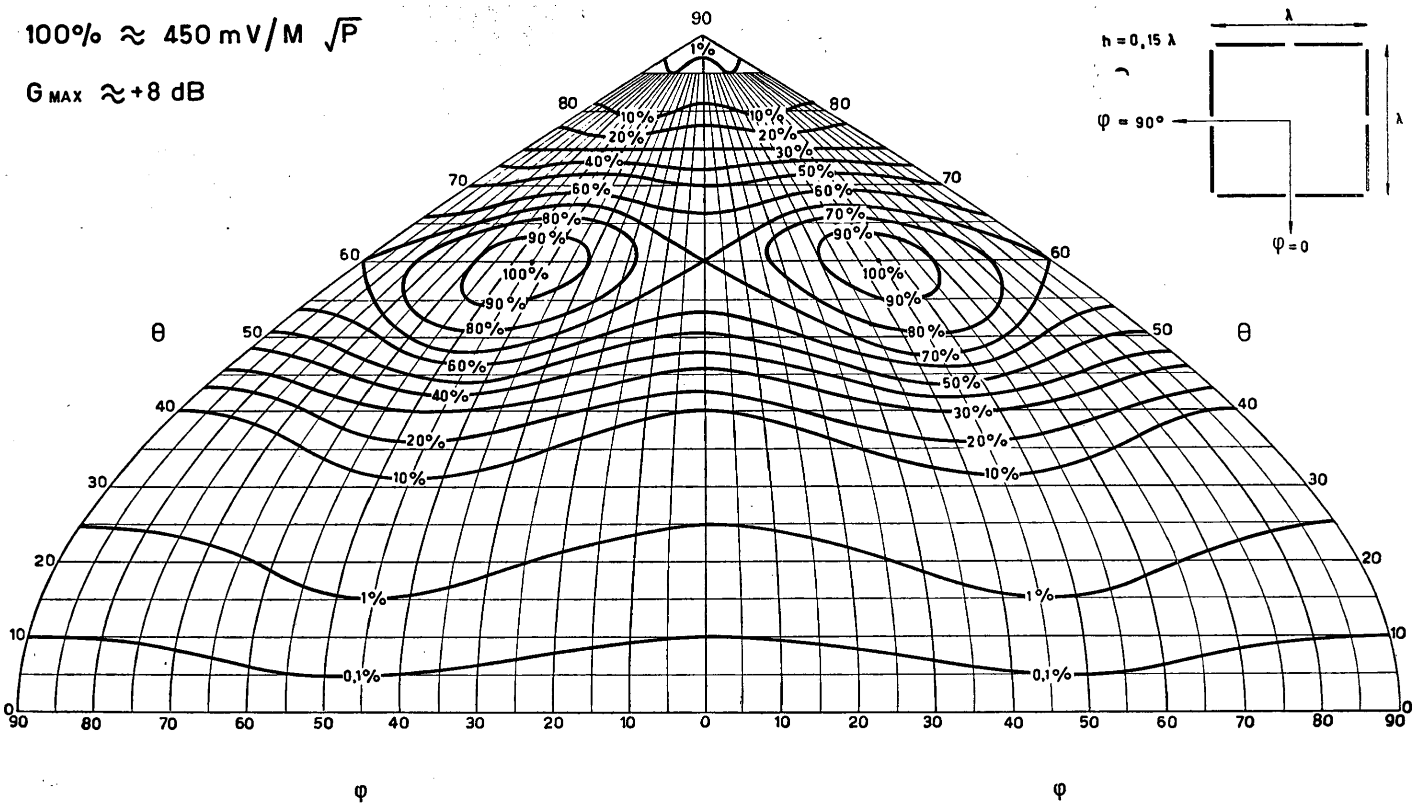


Figure 7

Power distribution diagram for the high-incidence array

ANNEX III

AN EXPERIMENTAL ANTENNA FOR BROADCASTING IN THE TROPICAL ZONE

(Doc. XII/4 (India), 1963–1966)

1. Introduction

Several types of antenna have been proposed from time to time in various countries for broadcasting in the Tropical Zone.

These are:

— a simple dipole,

— horizontal array of dipoles using 4 elements,

— horizontal array of dipoles using 16 elements,

— horizontal array of dipoles using 3 elements,

— omnidirectional system using four dipoles in a quadrant.

These antennae are erected at a low height (0·2 λ) above ground. All India Radio has been using a simple dipole erected at a height of 7/16 λ above ground.

These antennae suffer from one or more disadvantages. Simple dipoles give a service range beyond 1000 km. Horizontal arrays of dipoles with 4 or 16 elements give a range of about 300 km only, while a three-element horizontal array can provide a range of about 400 km but this requires special feed arrangements. The omnidirectional system requires considerable space and a large earth mat though it gives better signals in the range of 100 km to 400 km in the broadside-on direction, and 100 km to 1000 km in the end-on direction. These antennae have been specially designed to meet the requirements of the internal services of the country of origin.

2. A H-1/2-array fed out-of-phase

A simple two-tier dipole array with standard 0·5 λ spacing was considered with a view to developing an antenna for broadcasting in the Tropical Zone. A H-1/2/0·5 antenna fed in-phase gives an angle of fire of 17·5° with the horizontal while out-of-phase feeding raises this angle to 41°. Out-of-phase feeding can easily be arranged in such arrays, because of the standard 0·5 λ spacing between the elements. Such an antenna erected at a suitable height above ground would give the desired pattern.

3. Theoretical investigations

Theoretical investigations were first carried out to arrive at the best configuration which satisfied the general requirements of the antenna. The classical curtain theory was utilized for these computations. The computation showed that a H-1/2-array fed out-of-phase with the lower element at a height of 0·2 λ above ground satisfied the requirements. A typical vertical radiation pattern for a H-1/2/0·2 antenna fed out-of-phase is shown in Fig. 8.

4. Small-scale measurements

It was considered desirable to take measurements of the vertical radiation pattern before finally fixing the height above ground. This is because mutual effects at close spacings above ground would influence the current distribution in the elements and hence the vertical radiation pattern.

Full-scale measurements were excluded at the outset as the vertical radiation pattern would have to be measured with balloons or flying aircraft. The technique of small-scale measurements was therefore adopted. Scaling down to band 9 (UHF) was adopted in the context of available equipment and reasonable sizes for the swivelling structures for mounting the measuring antennae.

5. Results of small-scale measurements and correlation

Small-scale measurements showed that a height of 0·4 λ was more suitable than the theoretically computed height of 0·2 λ. This was attributable to the mutual effects due to the close spacings from the ground. The assumption of an image multiplying-factor based on the conventional array theory did not represent the case precisely. A method involving direct vectorial summation of group patterns of each dipole and its electrical image, taking into account the relative phase of the feed as well as the spatial phase difference of the two group patterns, gave a good degree of correlation (Fig. 9).

6. Full-scale measurements

Field trials were carried out on the full-scale antenna system with the parameters as determined in the small-scale model tests. Daytime measurements were decided upon as it would facilitate measurements in the open. Transitional periods during the late evening and early morning could thus be avoided and the effect of the ionosphere on the vertical radiation pattern minimized as far as possible. Daytime schedules to fit in the propagation conditions prevailing during the periods of survey were worked out. 49 m transmissions for the morning, early noon and late evening periods and 31 m for the afternoon periods were found feasible. The 49 m and 31 m H-1/2/0·5 in-phase fed arrays at our Regional Transmitter site were modified for out-of-phase feed, with a facility for feeding the lower element only for comparison purposes. (In the modified form these arrays have their lower elements at a height of 0·4 λ above ground and simulate very nearly a single dipole erected at that height above ground). A 5 kW short-wave transmitter was used for energizing these antennae.

The test transmissions were monitored and their field strengths recorded at various All India Radio stations approximately in the broadside-on direction. During each test transmission the single dipole (i.e. the lower element only) was energized and subsequently, after a brief break for change-over, the double dipole fed out-of-phase was energized. Comparative figures could thus be readily obtained.

Median values of measured field strengths were assessed from the records and curves of field strength as a function of distance were drawn for the 49 m and 31 m test transmissions. A typical curve representative of 49 m transmissions is shown in Fig. 10. The curve for 31 m transmission is similar. The values between 840 km and 1250 km were interpolated as measurements could not be taken at distances in between; from the nature of the curves obtained this was found possible.

7. Results

The results show that at distances up to about 600 km the fields put out by the experimental antenna are higher by a factor of 1·5 to 2 than from the single dipole. At larger distances the differences become smaller and at about 700 km, the field strength put out by the experimental antenna starts falling off. At about 850 km, it is about 2½ times down as compared with the single dipole.

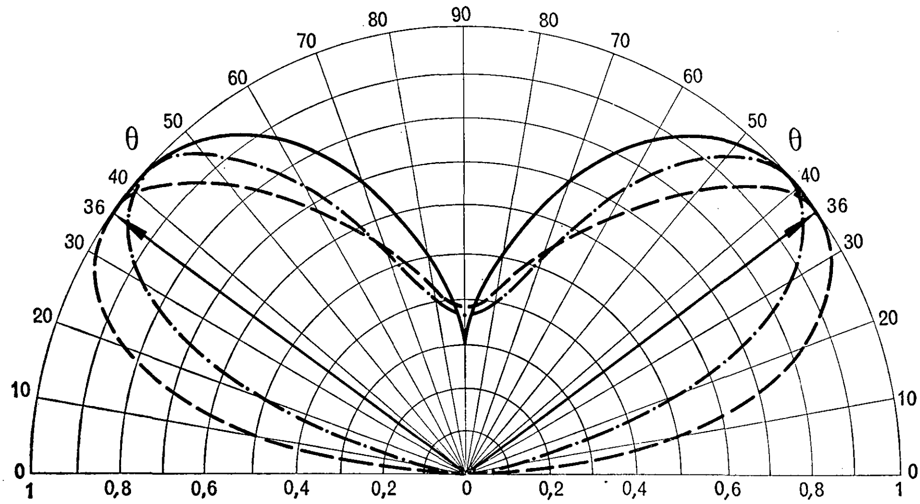


FIGURE 8

Vertical radiation patterns—idealized for 800 km distance and those obtainable by simple dipole and dipole array

——— Ideal
— — — Dipole 7/16 λ above ground
—·—· H-1/2/0·2 for out-of-phase feed

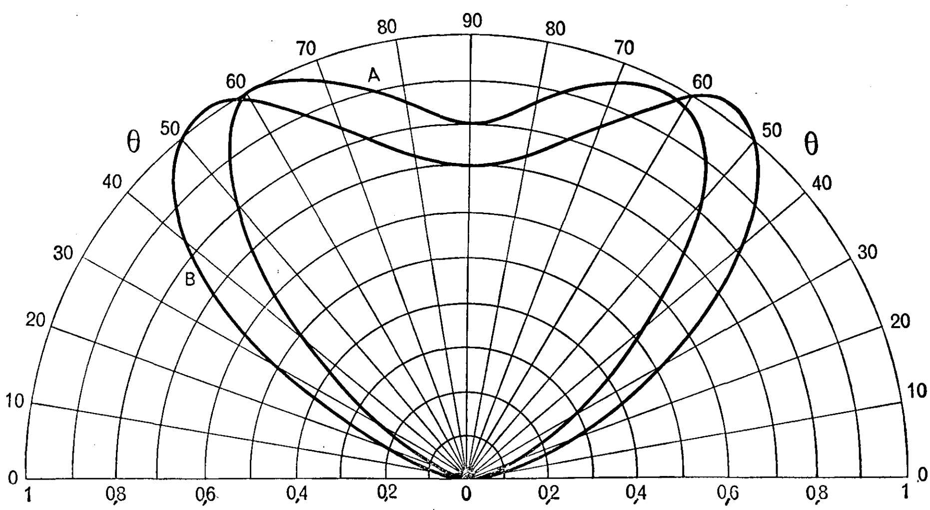


FIGURE 9

Vertical radiation patterns of H-1/2/0·4 array, out-of-phase feed

A: Curve computed by vector summation
B: Typical measured curve

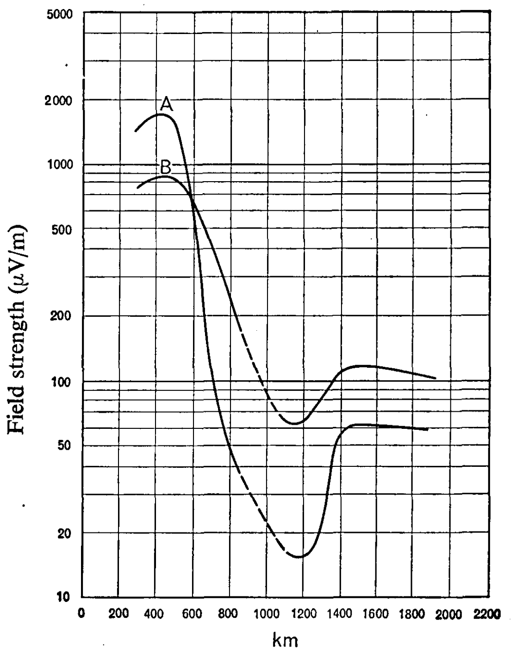


FIGURE 10

Experimental antenna for tropical broadcasting: field strength as a function of distance

Transmitter power = 5 kW
λ = 49 m

Curve A: H-1/2/0·4 array, fed out-of-phase
Curve B: H-1/1/0·4 comparison dipole
— — —: interpolated regions

ANNEX IV

DESIGN OF TRANSMITTING ANTENNAE FOR BROADCASTING IN THE TROPICAL ZONE

(Doc. XII/6 (India), 1966–1969)

The service area of a broadcasting transmitter in the Tropical Zone is usually considered as being primarily due to that provided by the 1-F mode, since losses due to the increased length of path and ground reflection generally make the contribution to the resultant field of the 2-F and higher modes negligible. But, when high gain antennae are used, it may happen that the reduction in the field due to path losses of the higher order modes are offset by the higher gain of the transmitting antennae at the angles of radiation for higher modes, especially at night-time.

The signal strength by different modes for two typical antennae:

— H-1/2/0·4 fed-out-of-phase;

— H-1/1/0·4

and their resultant have been worked out.

For H-1/2/0·4 antennae, the field strength does not fall off at night-time as rapidly as in daytime. This is due to the presence of significant fields arising from higher order modes.

Field-strength measurements have been carried out, which confirm the above conclusions (Fig. 11). It is considered that further studies should be undertaken to evolve a suitable antenna for night-time service, taking into account the possibility of more than one mode of propagation.

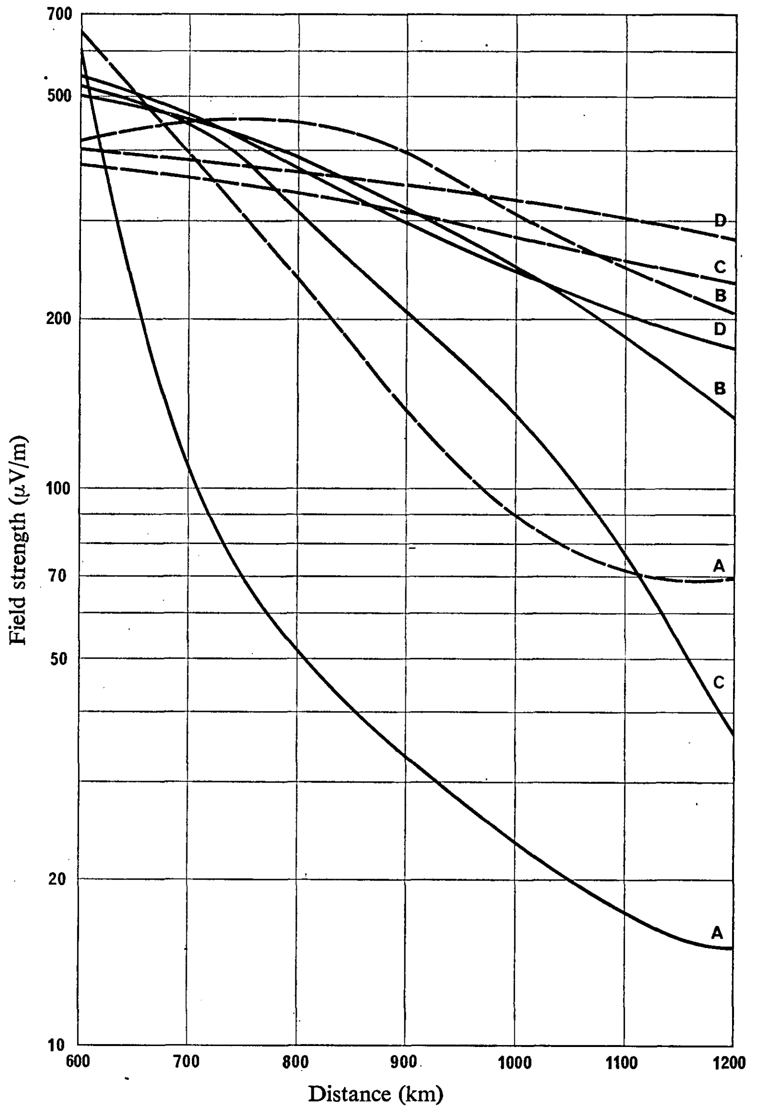


FIGURE 11

Field strength as a function of distance for an experimental antenna for broadcasting in the Tropical Zone

(Transmitter power 5 kW)

——— : H-1/2/0·4 array, fed out-of-phase

- - - - : H-1/1/0·4 dipole

Curve A: measured field strength: — day
Curve B: — night
Curve C: calculated field strength, night: — first hop field
Curve D: night: — resultant field

REPORT 302 *

INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING

(Question 27/10 and Study Programme 27C/10)

(1956–1959–1963)

This Report summarizes the results of the studies that were carried out to determine, by subjective tests, the ratios of wanted-to-unwanted signal required to satisfy various percentages of broadcast listeners.

1. Doc. 356 (India), Warsaw, 1956, 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 kHz, but with a filter giving an attenuation of about 8 dB at 5 kHz and a sharp cut-off above this frequency, was used.

For unwanted signals of classes of emission A2 and A3 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 Figs. 1-3 show the wanted-to-unwanted signal ratios required to provide 90%, 70% and 50% listener satisfaction for unwanted signals of classes of emission A2 telegraphy, A3 telephony and A3 broadcasting and for various frequency separations up to 5 kHz.

Table I gives the same information for:

— frequency separations of 0 kHz and 5 kHz exactly;

— nominal frequency separations of 0 kHz and 5 kHz under the most unfavourable conditions that could arise within the maximum permissible frequency tolerances of both wanted and unwanted signals, as specified in the Radio Regulations, Atlantic City, 1947.

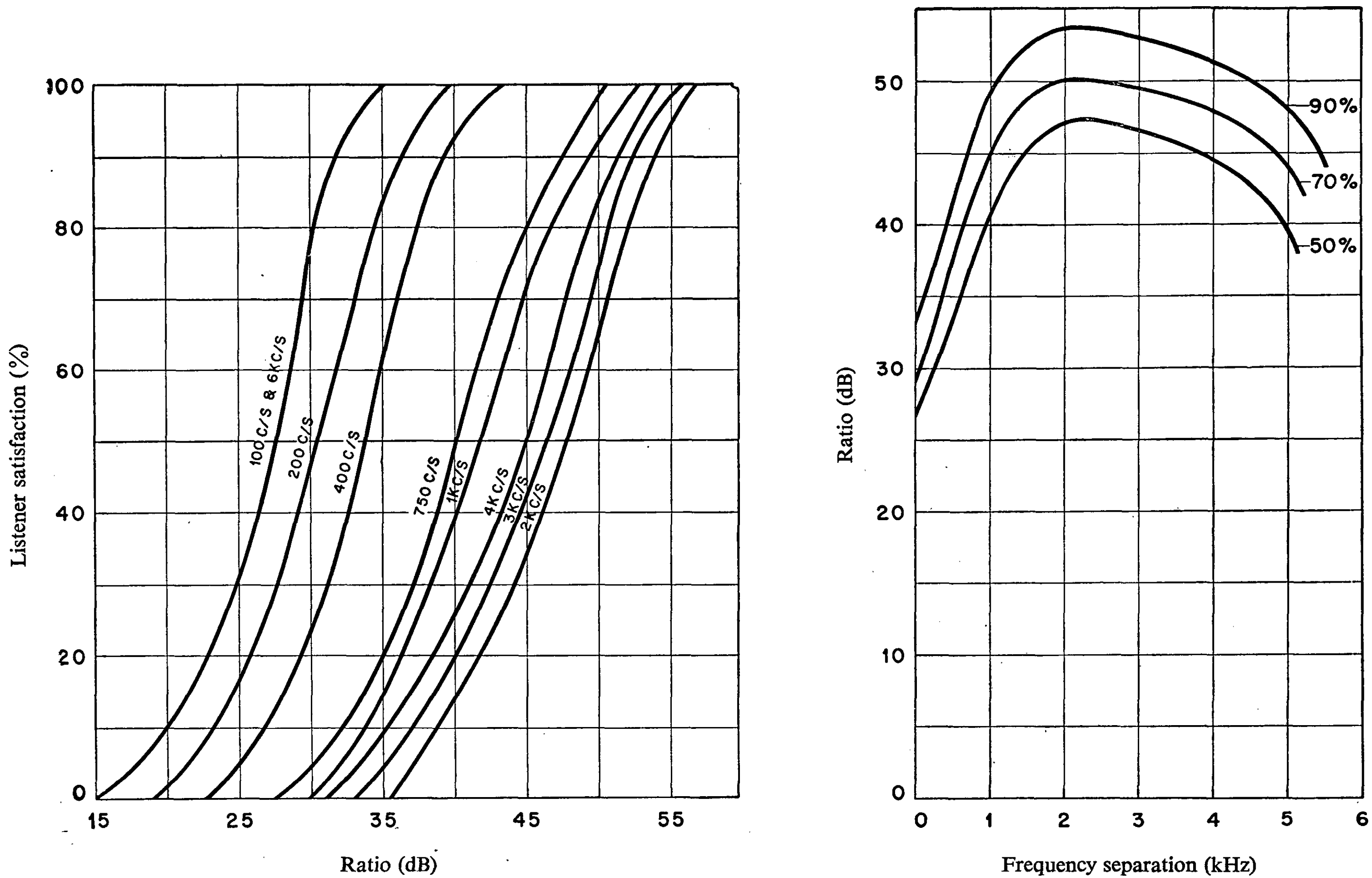
2. Doc. 231 (United Kingdom), Warsaw, 1956, gives details of the results of subjective tests made to determine the ratio of wanted-to-unwanted signal as a function of the frequency separation of the carriers of the two signals. Two typical broadcast receivers were used, having a fairly uniform response up to about 4 kHz falling to about — 8 dB to — 10 dB at 5 kHz. The unwanted signal was modulated by speech with a frequency range limited to 3 kHz. The ratio necessary to satisfy nearly all listeners varied from about 54 dB at 1 kHz separation, to a maximum of 56 dB between 2 and 3 kHz separation, falling to 52 dB at 5 kHz 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.

3. Doc. 553 (Federal Republic of Germany), Warsaw, 1956, gives the results of similar tests made with two types of receiver, one a narrow-band receiver with considerable attenuation above 3 kHz, and the other a wider-band receiver with an attenuation of about 8 dB at 5 kHz. 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 kHz, is 43 dB for 90% listener satisfaction.

* This Report was adopted unanimously.

TABLE I

Interfering emission	Maximum frequency tolerance (Radio Regs. 1947) (Hz)	Frequency separation (kHz)	Signal-to-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 Hz tone)	150	0	35	31	28	42	38	34
A2 — mobile (525 Hz tone)	1000	0	35	31	28	49	45	42
A3 — fixed (3 kHz maximum modulation)	150	0	33	30	28	40	36	33
A3 — mobile (3 kHz maximum modulation)	1000	0	33	30	28	50	47	44
A3 — broadcasting	150	0	33	30	28	44	40	36
A2 — fixed (525 Hz tone)	150	5	39	37	36	43	40	38
A2 — mobile (525 Hz tone)	1000	5	39	37	36	49	46	43
A3 — fixed (3 kHz maximum modulation)	150	5	48	44	40	50	46	42
A3 — mobile (3 kHz maximum modulation)	1000	5	48	44	40	52	48	45
A3 — broadcasting	150	5	48	46	44	49	46	44

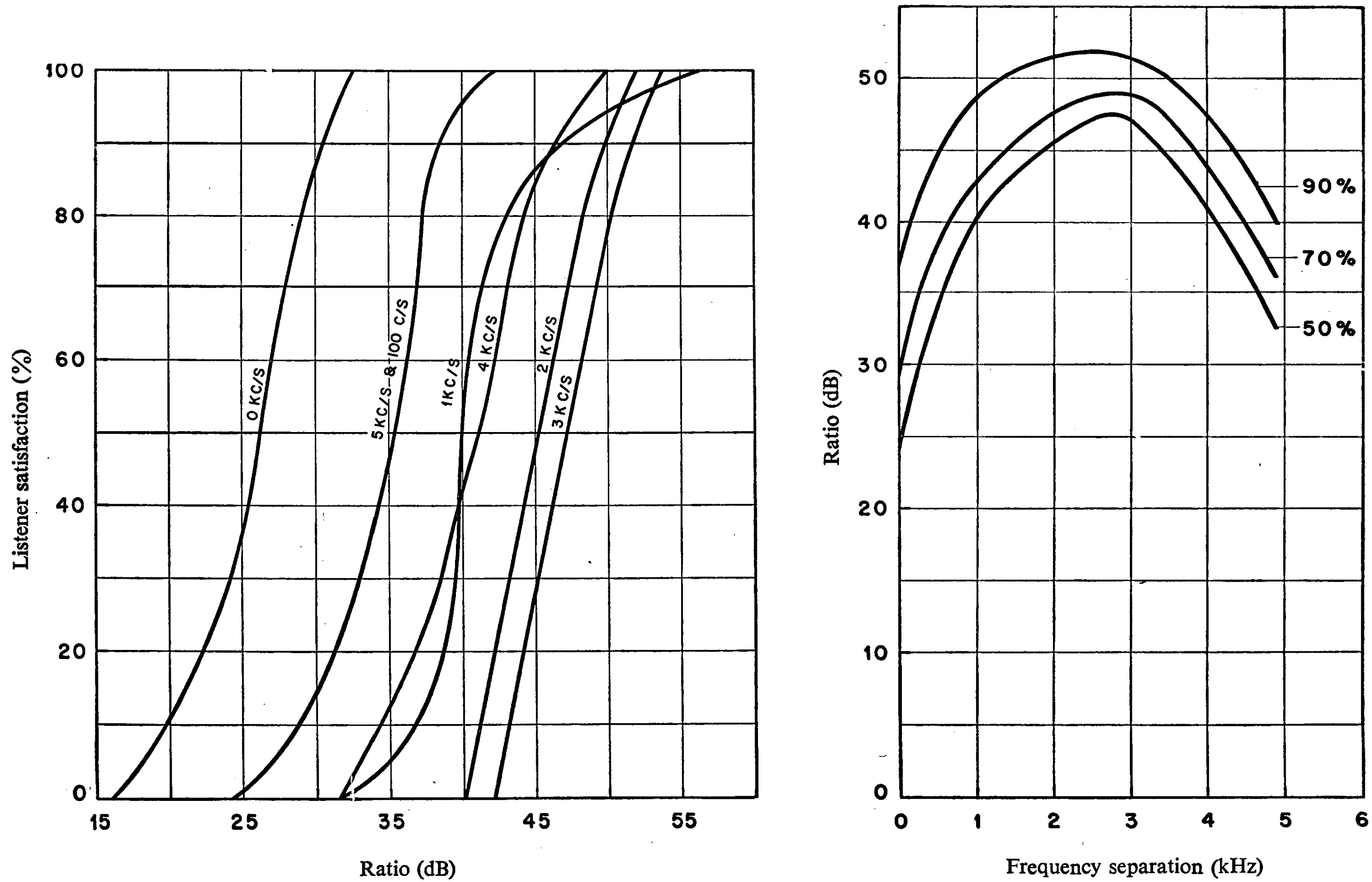


(a) Main programme: speech
Interference: A2 telegraphy

(b) Ratio of wanted-to-unwanted signal for 90%, 70% and 50% listener satisfaction

FIGURE 1

Wanted-to-unwanted signal ratio required against interference from A2 telegraphy

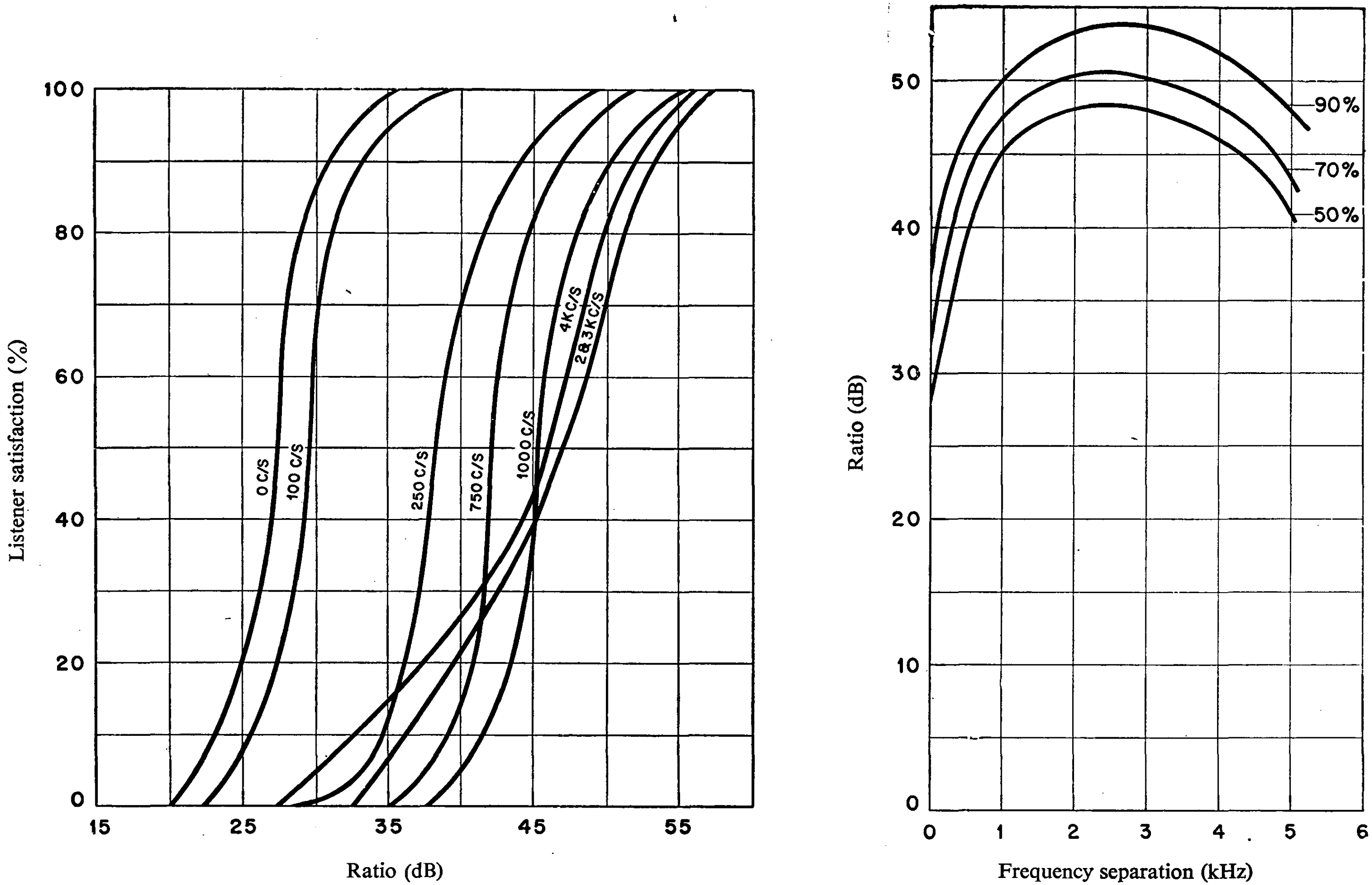


(a) Main programme: speech
Interference: A3 telephony

(b) Ratio of wanted-to-unwanted signal for 90%, 70% and 50% listener 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% listener satisfaction

FIGURE 3

Wanted-to-unwanted signal ratio required against interference from broadcast transmission

4. Comparison of the results arrived at in the three documents shows 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 ratio which provides the various degrees of listener satisfaction given in Table I and Figs. 1-3 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 signals was always predominant. This was the case for a frequency separation of 5 kHz between the two signals and, although the receivers used provided an attenuation of some 8 to 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 kHz 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 broadcasting in the Tropical Zone 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, the Republic of South Africa and the French Overseas Territories are of the opinion that a listener satisfaction higher than 50% should be provided. The Republic of South Africa and Australia consider that it would be impracticable to achieve 90% listener satisfaction from the aspect of signal-to-noise ratio, particularly under heavy static conditions, and therefore that, to aim at achieving 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 to 70% listener satisfaction.

5. Doc. XII/1 (United Kingdom), 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. 4. A summary of the conditions of the Post Office tests is also given in the document and is reproduced in § 3 of the Annex.

6. Doc. XII/6 (India), Los Angeles, 1959, describes work carried out in connection with Question 1/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 in § 4 of the Annex.

Doc. XII/6 takes into consideration the standards for frequency tolerances laid down in the Atlantic City Radio Regulations. The summary is confined to two limiting cases, namely frequency separations of 0 and 5 kHz respectively and indicates the protection ratios 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 listener 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 kHz. Any modifications to the design of broadcast receivers tending to attenuate frequencies at 5 kHz and lower will, therefore, result in serious deterioration in the quality of reception.

7. Doc. XII/7 (India), Bad Kreuznach, 1962, and Doc. 94 (India), Geneva, 1963, give results of further listening tests, in this case for frequency separations of 5-10 kHz. The experimental set-up was the same as before, except that, as recommended in Study Programme 1C/XI, filters with cut-off frequencies at 5, 6, 7, 8 and 9 kHz were incorporated at the output of the receiver. The wanted signal was modulated with a speech programme, the interfering signals were modulated with music, speech, A1 and A2 telegraphy (Morse — 525 Hz tone modulation). The document shows that on the basis of these experiments, which relate to values required for 90% listener satisfaction, the protection ratio required in each case gradually decreases as the carrier separation increases beyond 5 kHz and also as the cut-off frequency of the filter decreases. Table II gives the values of the protection ratios required when no filter is used in the output circuit of the receiver, for various types of interference.

TABLE II

Wanted signal	Interfering signal	Frequency separation (kHz)	Desired protection ratio (dB)
Speech	Music	5	46
Speech	Music	10	22
Speech	Speech	5	44
Speech	Speech	10	16
Speech	A2 telegraphy	5	38
Speech	A2 telegraphy	10	8
Speech	A1 emission	5	38
Speech	A1 emission	10	8
Music	Music	5	38
Music	Music	10	12
Music	Speech	5	38
Music	Speech	10	6

Note. — The protection ratios quoted refer in all cases to the ratios at the input to the receiver, no account having been taken of the effect of using directional receiving antennae or of the advantage that can be obtained by using different polarization for transmission of the wanted and unwanted signals.

With the incorporation of filters at the output of the receiver, the required protection ratios become less; the degree of reduction depends upon the frequency separation, the cut-off frequency of the filter and to some extent on the nature of the interference. The details are shown in Doc. XII/7, Bad Kreuznach, 1962 (Table II and Figs. 1 to 5) and Doc. 94, Geneva, 1963 (Table III and Figs. 1 to 3).

The documents conclude that, in assessing the required protection, the allowable frequency tolerance limits of various emissions must be taken into account. Considering the frequency tolerance standards, as laid down in the Radio Regulations, the increase in the required protection has been estimated. For a frequency of operation of 5 MHz, in the limiting case of interference from a broadcast station, the increase in required protection would be of the order of 2 dB for 5 kHz frequency separation and 1 dB for 10 kHz frequency separation. For frequencies of operation higher than 5 MHz, such protection ratios would be still higher. In the other limiting cases of interference from mobile stations, the increase in protection ratio at 5 MHz would be of the order of 4 dB for 5 kHz frequency separation and 3 dB for 10 kHz frequency separation. The incorporation of filters with lower cut-off frequencies would result in the reduction of the required protection ratios, only at the cost of the quality of received music programmes.

Since the results presented have been derived under steady-state conditions, appropriate allowance should be made for fading under actual operating conditions.

8. Doc. 218 (France), Geneva, 1963, describes the results of measurements of protection ratio made in the medium-frequency band under steady-state conditions on various types of receivers of recent manufacture.

The measurements were made by the usual method with a wanted signal and an unwanted signal, the level of the latter being set to give a level of interference considered tolerable by the listeners. Various types of programme were used for the tests but programme material particularly susceptible to interference (e.g. music of high quality with a wide dynamic range) and programmes only slightly susceptible to interference (e.g. modern dance music with a restricted dynamic range) were excluded.

The results of the measurements are shown by curve I of Fig. 4.

There are two main conclusions to be drawn from Doc. 218, namely that, for medium frequency reception at least, and with the great majority of receivers in use, the protection ratio necessary with no frequency separation ($\pm$ 20 Hz) is 40 dB, and with 5 kHz spacing, 46 to 50 dB.

The incorporation of special cut-off filters would reduce the required protection ratios, but only at the expense of quality of received music programmes.

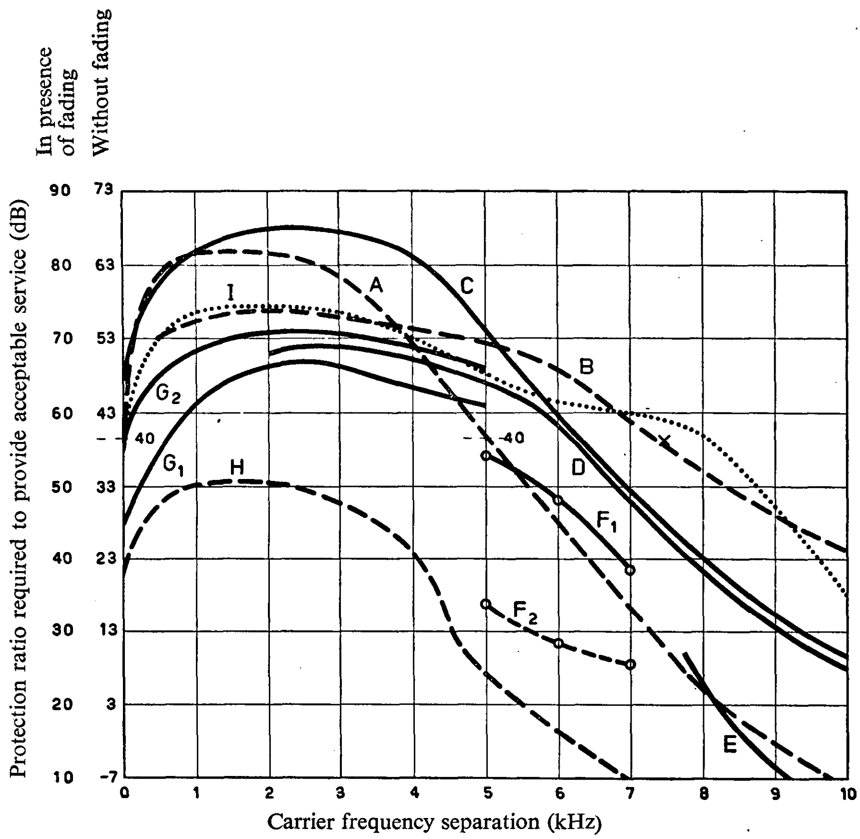


FIGURE 4

Protection ratios required to provide acceptable service

DESIGNATION OF CURVES

A* VAN DER POL (1933).
B* BRAILLARD (C.C.I.R., Bucharest, 1937).
C* B.P.O. tests, 1948.
D** B.P.O. tests, 1950.
E** B.P.O. tests, 1951.
F_1* B.P.O. tests, 1956 (no filter).
F_2** B.P.O. tests, 1956 (whistle filter).
G_1** Indian tests (50% satisfaction).
G_2** Indian tests (90% satisfaction).
H** Curve used by the I.F.R.B., 1956, for HF broadcast plans.
I*** French tests, 1962.

* Criterion of test—Just perceptible interference.
** Criterion of test—Just tolerable interference.
*** Corresponding to a " tolerable " interference for five different types of receivers.

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-Hz 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, 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. I, 241).

3. Conditions of tests for curves C, D, E and F (British Post Office tests)

The conditions under which tests 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

TABLE III

Test	Date of test	Wanted signal		Unwanted signal	
		Type	Modulation index	Type	Modulation index
C	1948	Music (0–8 kHz)	30% average, peaking to 100% occasionally	Speech (0–8 kHz)	30% average, peaking to 100% occasionally
D	1950	Broadcast speech	idem	Telephony (0–3 kHz)	70%
E	1951	Broadcast speech	idem	Speech (0–6 kHz)	30% average, peaking to 100% occasionally
F	1956	Broadcast speech	idem	Music (6 dB down at 4·6 kHz)	30% average, peaking to 100% occasionally

* *Note by the Director, 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. 4, 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).

practical evidence, this was taken to require the co-channel protection ratio to be increased to 33 dB. An allowance of 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 only with artificially produced short-term fading 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

TABLE IV

Wanted signal	Interfering emission	Frequency separation (kHz)	Protection ignoring frequency tolerance (dB)	Maximum frequency tolerance in the shared bands (Atlantic City) (Hz)	Protection taking into account the tolerance in column 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 Hz)	0	35	150	42
	A2-mobile (mod. at 525 Hz)	0	35	1000	49
	A3-fixed (mod. at 3 kHz max.)	0	33	150	40
	A3-mobile (mod. at 3 kHz 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 Hz)	5	39	150	43
	A2-mobile (mod. at 525 Hz)	5	39	1000	49
	A3-fixed (mod. at 3 kHz max.)	5	48	150	50
	A3-mobile (mod. at 3 kHz 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 Hz)	0	24	150	28·5
	A2-mobile (mod. at 525 Hz)	0	24	1000	36
Music (vocal)	A3-fixed (mod. at 3 kHz max.)	0	26	150	34
	A3-mobile (mod. at 3 kHz 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 Hz)	5	39	150	40
	A2-mobile (mod. at 525 Hz)	5	39	1000	43
Music (vocal)	A3-fixed (mod. at 3 kHz max.)	5	42·5	150	44
	A3-mobile (mod. at 3 kHz max.)	5	42·5	1000	46·5

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 kHz, could be assessed.

4. Conditions of test for curve G_2 (Indian tests with 90% listener satisfaction)

See Table IV.

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 (for stable transmitters ± 20 Hz). Any 5 kHz 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. Conditions of test for curve I

See § 8 of the Report.

7. 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. 4. 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 spacing of the order of 5 to 7 kHz, by as much as 12 to 20 dB.

REPORT 303-1 *

DETERMINATION OF NOISE LEVEL FOR BROADCASTING IN THE TROPICAL ZONE

(Question 31/10)

(1956-1959-1963-1966)

Question 31/10 calls for a comprehensive study of the characteristics of atmospheric noise in broadcasting areas in the Tropical Zone, and for its measurement by both objective and subjective methods.

1. Doc. 92 (India), Los Angeles, 1959, entitled " Determination of noise level for tropical broadcasting ", reports measurements of atmospheric noise made in Delhi, using an experimental arrangement, which is essentially an adaptation of that used in the Thomas method.

* 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.

FIGURE 1 *(Winter)*

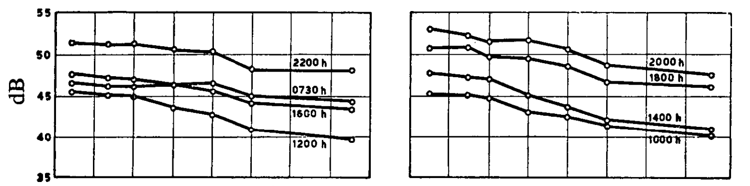


FIGURE 2 *(Equinox)*

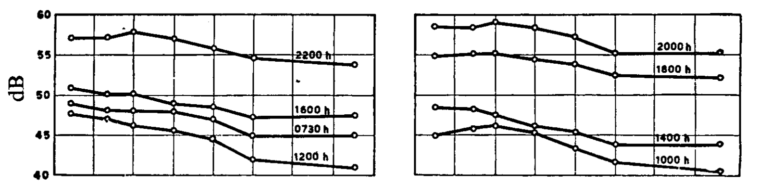
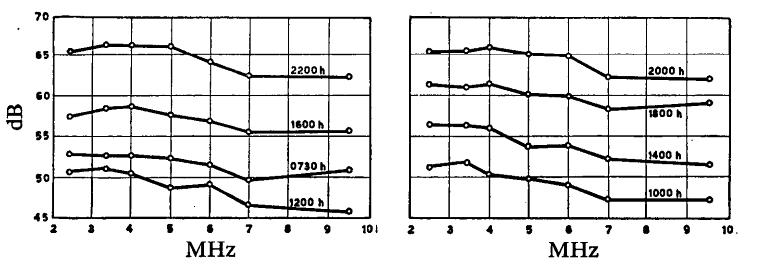


FIGURE 3 *(Summer)*



Minimum signal required for satisfactory listening (dB rel. 1 μV/m)

2. Doc. XII/10 (India), Bad Kreuznach, 1962, " Determination of atmospheric noise-level at Gauhati (26° 10′ N, 91° 40′ E) " and Doc. XII/11 (India), Bad Kreuznach, 1962, " Determination of atmospheric radio-noise at Trivandrum (8° 29′ N, 76° 57′ E) ", incorporate the values of atmospheric noise-level measured at Gauhati and at Trivandrum. The former is in the north-eastern part of India and the latter is in the southernmost part. The objective method described in Doc. 92 (India), Los Angeles, 1959, was used for these measurements. The thunderstorm activity in the eastern region of India is very high. The atmospheric noise-levels at Gauhati are therefore much higher than those in Delhi and its character is also impulsive of an intermediate type. On the other hand, the character of noise at Trivandrum is generally of the fluctuation type.

The seasonal averages of upper decile values of atmospheric noise-level at Gauhati for a receiver bandwidth of 6 kHz are given in Fig. 4. Similar values for Trivandrum are given in Fig. 5. Noise levels at Trivandrum have been reported, on the basis of measurements for one year and the values should be taken as tentative.

3. Doc. XII/6 (U.S.A.), Bad Kreuznach, 1962, " Determination of noise level for tropical broadcasting ", mentions that a measuring equipment (ARN-2) has been developed by the Central Radio Propagation Laboratory of the National Bureau of Standards, United States of America, for obtaining an objective measure of the average power, average voltage and average logarithm of the voltage of the noise envelope. It has also been stated that a method has been developed for determining the amplitude probability distribution function of the radio-noise envelope from these three measured parameters.

There are sixteen such recorders in operation in different parts of the world, with eight of these stations in the Tropical Zone. To determine the relationship between the noise received on a vertical antenna and on a horizontal antenna, the ARN-2 is to be used to record on a time-sharing basis from three antennae, the standard vertical whip, a horizontal antenna oriented North-South and a horizontal antenna oriented East-West.

Report 65 has been revised (Report 322) using data obtained during the last few years. Until supplementary information is available for further revision of Report 322, the data contained in Report 322 should be used with some caution in predicating noise conditions in tropical areas.

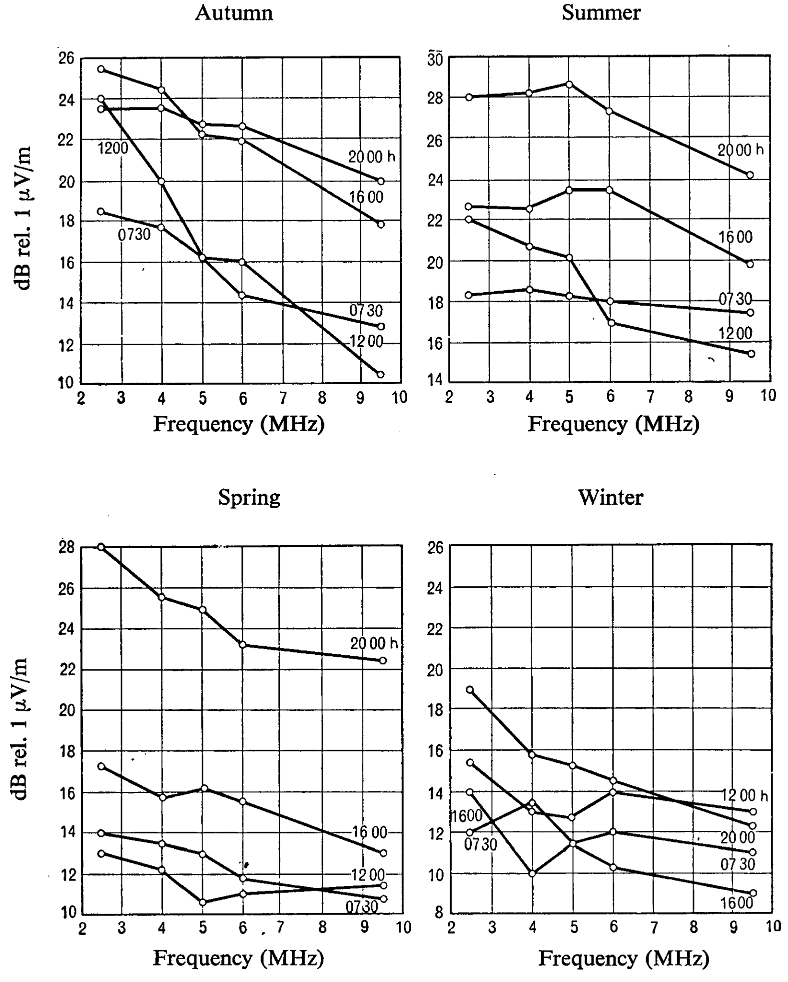


FIGURE 4

Atmospheric radio-noise at Gauhati

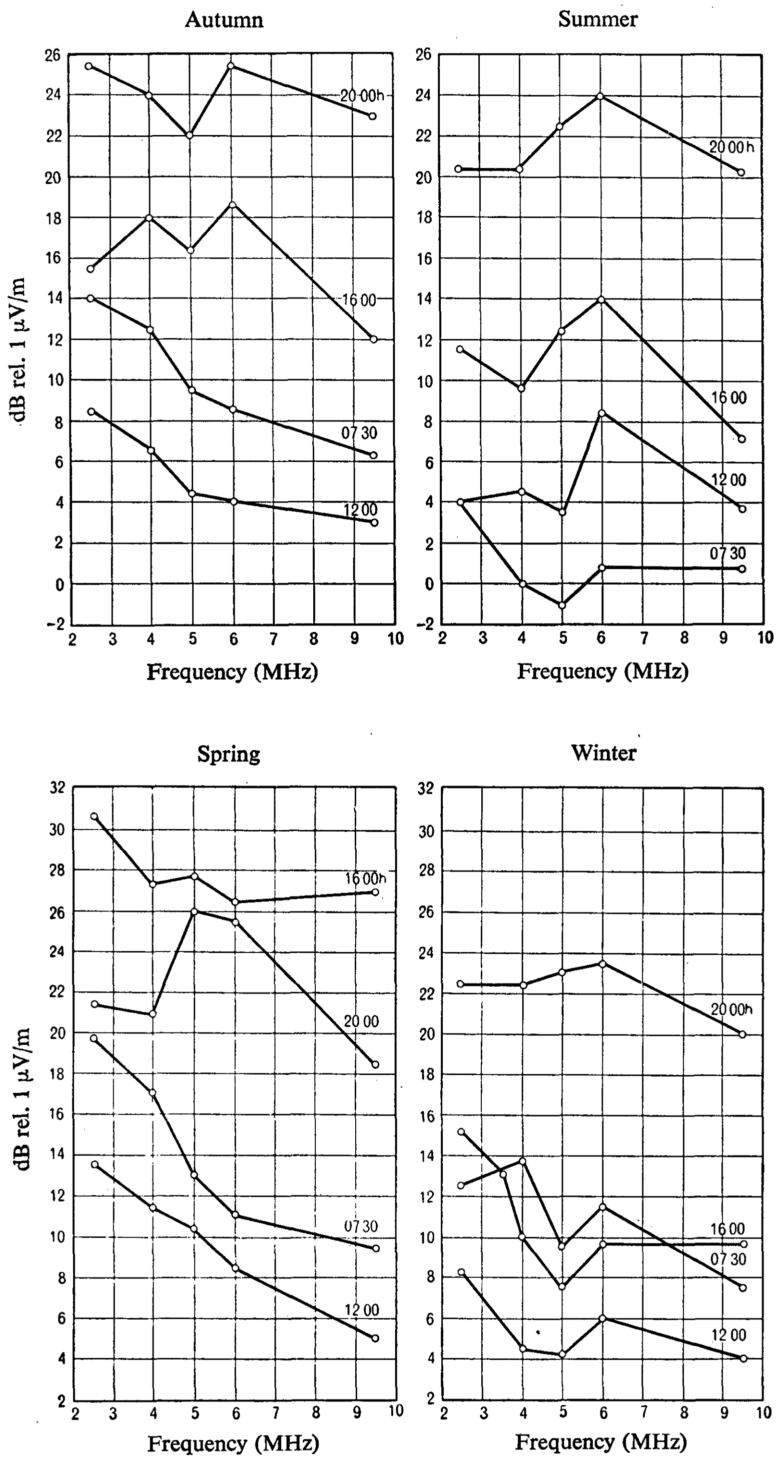


FIGURE 5

Atmospheric radio-noise at Trivandrum

4. Doc. XII/5 (India), 1963-1966. Determination of atmospheric radio noise in India for tropical broadcasting

4.1 *Introduction*

Measurements of atmospheric radio-noise in different locations in India have been continued since 1955 by All India Radio to cover the subject mentioned above. Report 303-1 summarizes the results of measurements contained in various documents, submitted to the C.C.I.R. by India and other countries. The information, presented in this section of the Report, is in continuation of that already used for the preparation of Report 303-1 and in pursuance of the directions embodied in Resolution 32 and Study Programme 27A/10.

4.2 *Measurement*

The upper decile values of atmospheric radio-noise field strengths, averaged over the period recorded so far, have been presented for all the four seasons at different hours of measurement for the measuring stations at Delhi (28° 35′ N, 77° 05′ E), Trivandrum (8° 29′ N, 76° 57′ E) and Vishakhapatnam (17° 41′ N, 83° 18′ E). These are shown in the form of graphs in Figs. 6–8.

For Delhi, the same subjective method of Thomas and Burgess, but suitably modified for broadcasting as reported earlier, was followed to collect data from 1955 till the middle of 1964. Measurements at Trivandrum were started in 1960 and the data presented are up to the middle of 1965. The data for Vishakhapatnam are for the period April, 1964 to July, 1965 and as such these data may be considered to be only tentative.

The values are for the times 0730, 1200, 1600 and 2000 hours IST (IST = GMT + 5½ h) and at the frequencies 2·5, 3·4, 4·0, 5·0, 6·0, 7·0 and 9·5 MHz. The measurements at 3·4 and 7·0 MHz at Trivandrum were introduced in November, 1963 only. Measurements on 4·0 MHz at Vishakhapatnam were not carried out.

4.3 *Results*

Delhi is a station in the northern part of India and in general, noise intensities in this location are highest at night in summer and lowest at noon in winter. But such a situation is not found for Trivandrum and Vishakhapatnam which are sea-coast stations in the southern part of India. Both for Trivandrum and Vishakhapatnam, unlike Delhi, maximum noise intensities are observed at night in the spring instead of in the summer, although minimum noise values, like Delhi, are obtained during winter noons. Besides, for Trivandrum the variations in noise levels at different frequencies for any particular season appear to be rather anomalous. Trivandrum, apart from being on the sea-coast, is on the magnetic equator. Its geomagnetic latitude is 00° 54′ S and magnetic dip is 0°. Before arriving at any significant conclusion in respect of the fact that propagation of noise is likely to be influenced in an anomalous manner due to the nearness of the measuring station to the magnetic equator, further measurements and collection of data are necessary. To facilitate the study in detail, noise data from another sea-coast station in Southern India, but away from the magnetic equator, namely Vishakhapatnam, are being collected.

Measurements at Trivandrum and Vishakhapatnam are being continued.

4.4 *General remarks*

From a comparison between the data presented earlier for Delhi and Trivandrum and those that are presented now, it may be seen that there is a general increase in noise intensities in these measuring locations. Both propagation and thunderstorm activities seem to be affected by the sun-spot cycle and, therefore, some correlation is to be expected between sunspot activity and propagated atmospheric radio-noise field strengths. But although, till now, no such correlation has been reported, increase in propagated noise field intensities during lower sunspot activities is perhaps expected.

However, before any definite conclusion is arrived at, further studies are necessary.

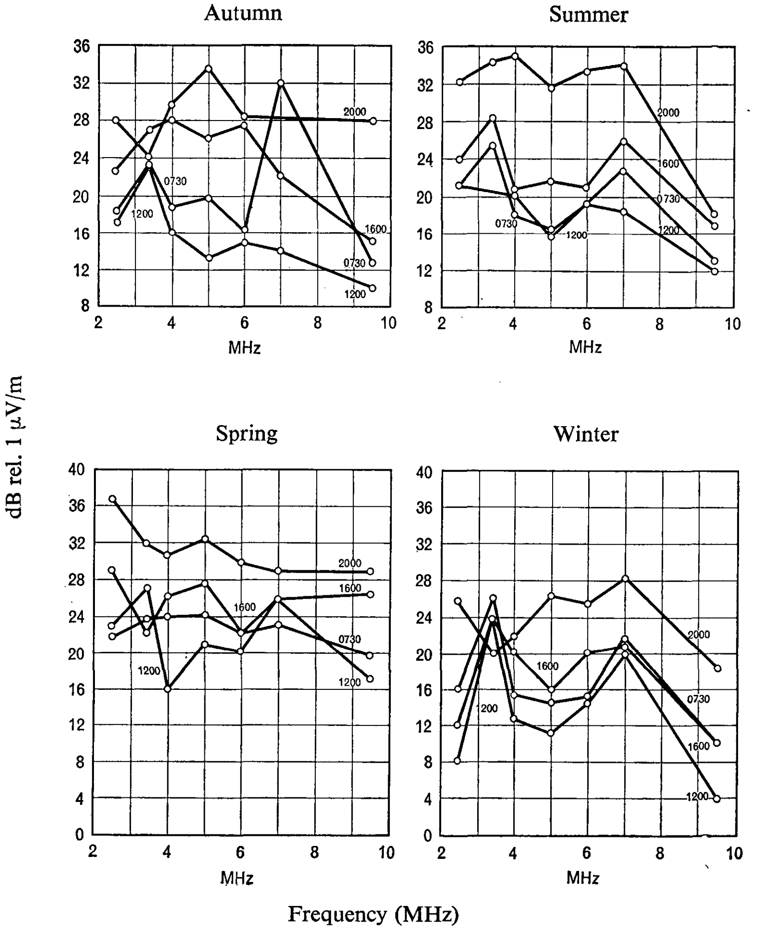


FIGURE 6

Seasonal variations of average upper decile values of atmospheric radio-noise field strengths measured at Trivandrum

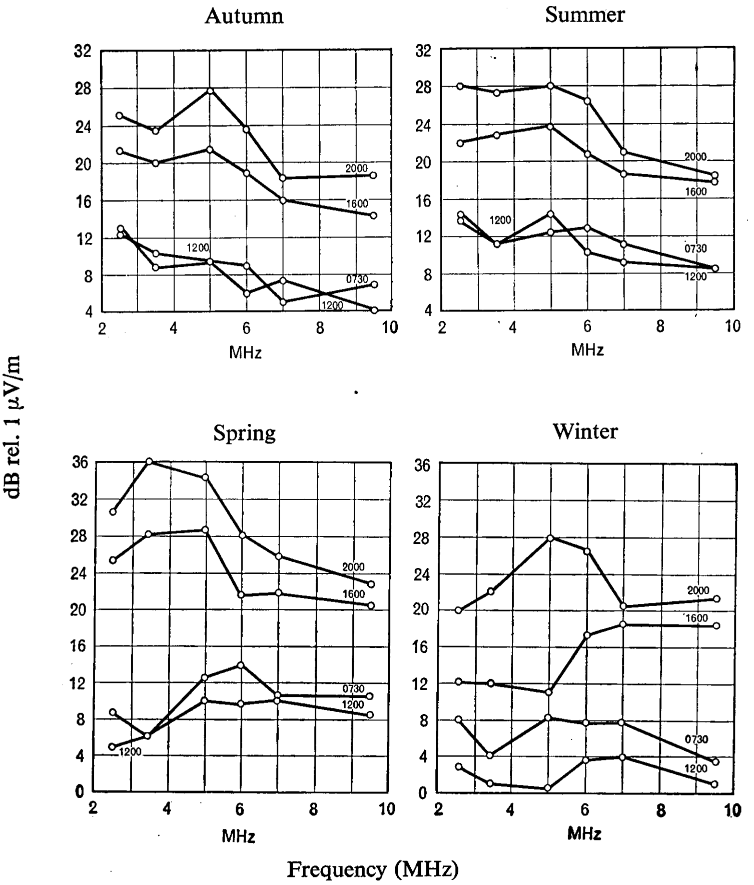


FIGURE 7

Seasonal variations of average upper decile values of atmospheric radio-noise field strengths measured at Vishakhapatnam

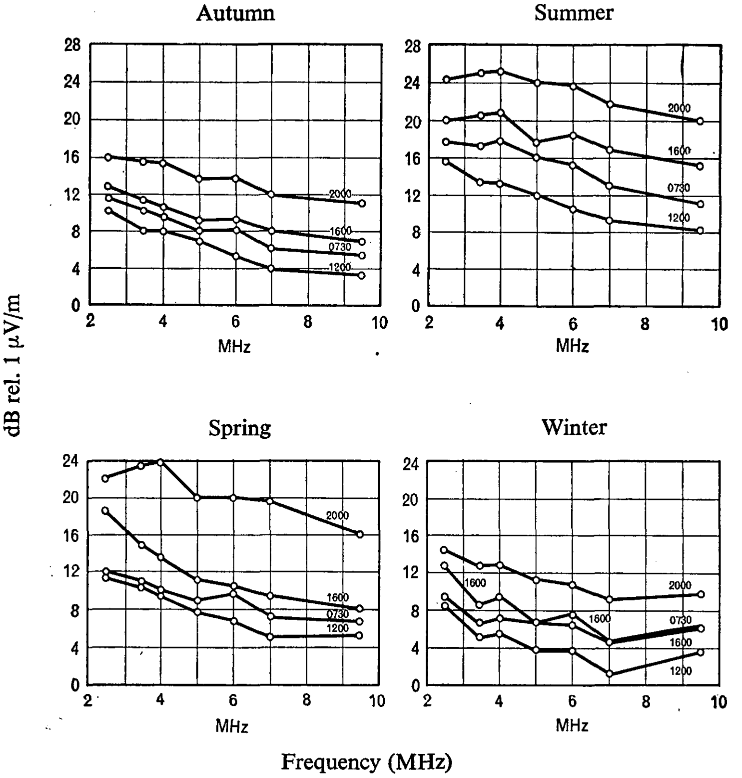


FIGURE 8

Seasonal variations of average upper decile values of atmospheric radio-noise field strengths measured at Delhi

REPORT 304 *

FADING ALLOWANCES FOR BROADCASTING IN THE TROPICAL ZONE

(Question 30/10)

(1956 - 1959 - 1963)

Question 30/10 calls for a study of the characteristics of fading in the Tropical Zone, on assessment of the annoyance value of fading to reception from the point of view of listener satisfaction and determination of the allowances that should be provided for fading when planning broadcasting services in the Tropical Zone.

The following is a summary of contributions received in response to this Question:

1. Doc. XII/8, Los Angeles, 1959 (Preliminary report on the statistical analysis of fading on short-wave transmission)

This contribution from India describes experiments in the measurement of fading of continuous-wave emissions at oblique-incidence, voice-modulated broadcast transmissions on 4·7 MHz, 9 MHz and 15 MHz, 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 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 CW transmission, and

— the equivalent vertical-incidence frequency for pulse transmission with reflection; both records are 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 CW signal, owing to the large distances separating them.

2. Doc. XII/12, Bad Kreuznach, 1962 (A report on the severity of fading on short waves)

This contribution from India discusses quantitative estimates of the severity of fading, and the effects upon fading of such factors as time of day, season and geographical location for oblique-incidence transmissions. The report concludes that:

2.1 Based upon fading measurements conducted at Nagpur by the Research Department, All India Radio, using transmissions from four regional short-wave broadcasting stations at Delhi, Bombay, Madras and Calcutta over a three-year period, the ratio between the monthly median and the monthly lower decile values of the hourly-median field intensity was found to vary from 1·0 to 15·4 dB. The overall median value was 7·4 dB with a standard deviation of 2·9 dB. The overall average was 7·6 dB. Morning and midday ratios were generally higher

* This Report was adopted unanimously.

than the night values. Night values remained at approximately the same level regardless of season for Delhi, Bombay and Calcutta, while daytime values fluctuated with the season. In Madras, night values were higher in winter and equinox months than in summer. The average ratio was not found to vary much among the four locations measured, although there were times when the instantaneous value observed from one location was considerably different from the others.

2.2 The diurnal and seasonal variations of the ratio between the monthly median and the monthly lower decile values of the hourly-median field intensity appear to show a good correlation with the occurrence of sporadic E and the variations of absorption. It appears reasonable to assume, therefore, that the day-to-day fluctuations of the received signal are caused by sporadic-E reflections, variations of absorption and, under appropriate conditions, by multi-hop transmissions.

2.3 Based on the analysis of field-strength recordings made at Patna of short-wave broadcast transmissions from Srinagar, Bombay and Madras, as well as of the signals of regional short-wave transmitters referred to in § 2.1, which were measured at several locations in India, the ratio between the median signal level and the received signal intensity exceeded 90% of the time, was found to vary from 1·6 to 27 dB. The most probable value was found to be 9 dB. The highest ratio occurred at approximately 2200 hours, both for summer and winter months, with average levels generally higher during the late afternoon and evening hours than during the morning and midday periods. Ratios during the summer months were approximately 4 dB higher, on the average, than values observed during winter periods.

2.4 On comparing the observed data with those obtained by other countries, it is found that fading, as referred to instant-to-instant variations in field strength, appears to be more severe in India than in countries in the temperate zones. The day-to-day fluctuations, however, appear to be of the same order as in the temperate zones.

3. Doc. XII/5, 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 in the Tropical Zone. 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 recording made in three broadcasting areas in the Tropical Zone 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 steps of 4 dB.

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 period around 1800 hours local time.

3.1 The results showed little dependence on location of transmitters or time of the day. However, they appeared to show some small dependance on range and have therefore been grouped under three ranges, 0-100 km, 100-350 km and over 350 km.

3.2 The fading experienced in the 100-350 km range is somewhat less than that for the other two ranges. This has been attributed as possibly due to inter-action between ground and one-hop sky wave for 0-100 km and multipath sky-wave propagation for over 350-km groups.

3.3 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 s. Another feature noticed is the increased rate of fading experienced after local sunset.

4. Doc. XII/17, Bad Kreuznach, 1962 (Fading allowances for tropical broadcast transmissions)

This contribution by the United Kingdom describes the results of more recent fading measurements carried out at Barbados and Trinidad, Ghana, Singapore and Johannesburg along the lines discussed in § 3. The additional data cover, for the most part, ranges exceeding 350 km, and have been combined with those obtained previously, to provide a more statistically stable sample. The additional results confirm earlier conclusions, that the short-term fading characteristics for ranges between 0 and 350 km conform closely with that of a Rayleigh type of distribution. The inclusion of additional data for ranges in excess of 350 km, however, indicates a greater departure from a Rayleigh type of distribution than from previous data. The characteristics of the received signal waveforms were, in general, similar to those analysed previously, showing a tendency for an increased rate of fading after local sunset.

5. Doc. XII/5, Bad Kreuznach, 1962 (Equatorial effects in broadcasting in band 7 (HF))

This contribution by the United States is devoted mainly to a discussion of equatorial flutter fading, which the paper considers to be the most serious of the several propagation effects peculiar to equatorial regions, from the standpoint of circuit degradation.

5.1 The document discusses published observations of equatorial flutter, which appears to be most serious within a geographical area defined by a belt of width between 650 and 1300 km centred on the magnetic equator. To date, data are available mainly from the Far East and Africa and it is not certain that the belt is uniformly wide around the world. It appears that north-south circuits, with a reflection point in the critical belt, may be more affected than east-west circuits, with the same reflection point. The fading effect is most intense within two hours of local sunset at the point where the propagation path crosses the magnetic equator. All evidence seems to point to the fact that equatorial fading is most serious during sunspot maximum and becomes almost negligible during periods of sunspot minimum. Seasonal variation, however, is not nearly so well defined, but it appears that equatorial flutter fading is more intense during the equinoctial periods than during the other seasons.

5.2 Signal degradation, caused by equatorial flutter, appears to be equally serious throughout the entire audio spectrum. Subjectively, its effects are more noticeable on musical transmissions than on speech. A Doppler effect has been observed up to 40 Hz.

REPORT 305-2 *

BEST METHOD FOR CALCULATING THE FIELD STRENGTH PRODUCED BY A BROADCASTING TRANSMITTER IN THE TROPICAL ZONE

(Question 28/10)

(1963 – 1966 – 1970)

1. Introduction

Docs, 227 and 357, Warsaw, 1956, considered the currently used C.R.P.L. and S.P.I.M. methods for calculating the sky-wave field strength from a broadcast transmitter in the Tropical Zone. At the VIIIth Plenary Assembly, Warsaw, 1956, Study Group XII 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 2/XII (now Question 28/10) were submitted to the IXth Plenary Assembly, Los Angeles, 1959: Docs. XII/2 (United Kingdom), XII/3 (French Overseas Territories) and XII/7 (India). The following documents were received during the period 1960–1962 and considered at the Interim Meeting of Study Group XII Bad Kreuznach, 1962: Docs. XII/8 (India), XII/9 (India) and XII/18 (United Kingdom). These documents, together with Doc. 98 (India), Geneva, 1963, Doc. XII/3 (India), 1963–1966 and Doc. XII/4 (India), 1966–1969 are summarized in this Report.

2. Doc. XII/2 (United Kingdom), Los Angeles, 1959

Question 28/10 asks what is the best method for calculating the field strength produced at the surface of the earth by the indirect ray, by a transmitter situated in the " Tropical Zone " (as defined in Nos. 135 and 136 of the Radio Regulations) under various conditions and, in particular, at distances up to 800 km and from 800 to 4000 km from the transmitter.

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 these 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 28/10.

In effect, the method proposed is comparable with that given in Circular No. 462 of the National Bureau of Standards in the United States of America. 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 (Malaysia) 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 data of Circular No. 462.

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 signals in band 7 (HF) reflected at steep angles of incidence from the ionosphere, but it is hoped that studies being made in this and other countries of Question 28/10 will provide the necessary quantitative data.

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* This Report was adopted unanimously.

** PIGGOTT, W. R.: The calculation of the median sky-wave field strength in tropical regions. D.S.I.R. Radio Research Special Report 27, H.M. Stationery Office, London, 1958.

Attention 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.

3. Doc. XII/3 (French Overseas Territories), Los Angeles, 1959

This document discusses the main characteristics of broadcasting in the Tropical Zone. It 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 is given and certain conclusions concerning the main requirements for a rational use of broadcasting in the Tropical Zone 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 angle of transmission would have to be used.

3.1 *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.

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.

3.2 *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 μV/m, which is regarded as practicable for listeners with an ordinary six-transistor receiver and generally sufficient to procure a signal-to-noise protection ratio better than or equal to 40 dB.* However, at periods of intense noise, it is advisable to take higher reference field values for low frequencies.

* In India, it has been found that a much higher field-strength is required to give a satisfactory service.

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.

3.2.1 *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 wavelength 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.

3.2.2 *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 wavelength, transmitting vertically. Fig. 2 *(b)* shows that of a single-slot antenna, at a height of 0·4 wavelength, 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 wavelength, without there being an increased risk of interference in the area beyond 800 km (500 miles) from the transmitter.

3.2.3 *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 wavelength above ground. The moment considered, for each graph, is 0800 hours LMT, in June (R = 10). The frequency is 5 MHz. 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 MHz.

3.2.4 *Comments on Figs. 4 (a) and 4 (b)*

These two graphs were drawn up for a half-wave antenna at a height of 0·25 wavelength, 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 at 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 wavelength 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.

4. Doc. XII/7 (India), Los Angeles, 1959 and Doc. XII/8 (India), Bad Kreuznach, 1962

These two documents report the results of further measurements on ionospheric absorption at Delhi, some of which were reported earlier in a document of the VIIIth Plenary Assembly. The main conclusions are summarized below:

4.1 *The diurnal variation of absorption*

The diurnal variation of absorption may be expressed by the relationship

$$| \log \rho | = k (\cos \chi)^n \qquad (1)$$

where

ρ : apparent reflection coefficient,
$-\log \rho$: measure of absorption,
χ : solar zenith-angle.

Since, however, the exploring wave frequency of 5 MHz used in the investigation has not always been much higher than the critical frequency of E layer during midday, deviative absorption in penetrating the E layer might contribute towards the total absorption measured.

Following Jaeger's method, the absorption suffered in penetrating the E layer was calculated and subtracted from the total absorption. The value of n_D for the non-deviative absorption in the D-layer has also been determined. The values of n and n_D during various seasons are given in Table I.

TABLE I

Diurnal variation factor n and n_D

Season	Forenoon			Afternoon			Mean of forenoon and afternoon values		Weighted average	
	Number of observations	n	n_D	Number of observations	n	n_D	n	n_D	n	n_D
Summer (May, June, July, August)	11	1·05	0·86	8	0·94	0·77	1·0	0·81		
Equinox (March, April, September, October)	8	0·99	0·82	11	0·96	0·80	0·97	0·81	0·92	0·77
Winter (November, December, January, February)	13	0·88	0·74	21	0·82	0·72	0·84	0·73		

It will be seen from this Table that the mean value of n_D works out to be 0·77.

4.2 *The seasonal variation of absorption*

The seasonal variation of absorption may be expressed by the relationship

$$|\log \rho| = k' (\cos \chi_{\varphi=0})^m \qquad (2)$$

where $\chi_{\varphi=0}$ is the solar zenith-distance at zero hour-angle. The values of m and m_D have been found to be distinctly lower than the average values of n and n_D. This leads to the conclusion that there is slightly more absorption during winter than would have been expected from the value of n and n_D given in § 4.1. The winter anomaly has also been reported from an analysis of Slough data.

4.3 *The sunspot-cycle variation*

The sunspot-cycle variation may be expressed by the relationship

$$A_R = A_0 (1 + C\overline{R}) \qquad (3)$$

where

A_R = absorption when the sunspot is R,
A_0 = absorption when the sunspot number is zero,
C = sunspot cycle variation factor,
$\overline{R}$ = running average sunspot number.

The value of C was found to be 0·0017.

4.4 *Night-time absorption*

During most of the time, absorption at night was found to be low. The mean value of night-time absorption was found to be 2·5 dB. On a few nights, however, the absorption was abnormally high.

4.5 *Frequency variation of absorption*

The frequency variation of absorption may be expressed by the relationship

$$|\log \rho| = k'' (f \pm f_L)^{-n_f} \qquad (4)$$

where

f : frequency of the radio-wave; and

f_L : longitudinal component of the gyromagnetic frequency.

The average value of n_f was found to be 1·8 and no significance can be attributed at this stage to the fact that the value of n_f is slightly less than 2·0 as predicted from theory.

5. Doc. XII/9 (India), Bad Kreuznach, 1962; Doc. 98 (India), Geneva, 1963; Doc. XII/3 (India), 1963–1966 and Doc. XII/4 (India), 1966–1969

The Research Department of All India Radio has used the non-deviative absorption measured at Delhi to evolve a formula for calculating the sky-wave field intensity in tropical regions. Doc. XII/9 describes the various considerations used to work out the formula, and provides curves for field strength by the 1-F propagation mode. It compares the results obtained by its use with those achieved by other means. Additional field-strength measurements and calculations are given in Doc. 98. Doc. XII/3 extends this method to the 2-F propagation mode, and provides curves for the calculation of the E-layer cut-off frequency. Doc. XII/4, 1966–1969, has presented further developments, consisting of a set of ten curves, whereby the field strength for any circuit by any mode of propagation can be read directly.

5.1 *Factors involved in the estimation of field strength*

The field strength produced by a transmitter operating in band 7 (HF) at any distance may be expressed as:

$$F = F_0 + a_1 + a_2 - (a_3 + a_4 + a_5 + a_6 + a_7 + a_8) \qquad (5)$$

where

F = field strength (dB rel. 1 μV/m),

F_0 = field strength (dB), produced at unit distance (1 km) by a transmitter of unit power (1 kW) using an antenna of unit gain (i.e. omnidirectional),

a_1 = power gain of the transmitter (dB),

a_2 = gain of the transmitting antenna (dB),

a_3 = losses due to spatial attenuation (dB) (focusing, if any, is included),

a_4 = losses due to non-deviative absorption (dB),

a_5 = losses due to deviative absorption (dB),

a_6 = losses due to ground reflection for multi-hop propagation (dB),

a_7 = losses due to the non-linear polarization of the downcoming wave (dB),

a_8 = losses due to partial reflection as in the presence of Es (dB).

The field produced at 1 km by a 1-kW transmitter using an omnidirectional antenna may be taken as 173·8 mV/m. This gives a value of 104·8 dB for F_0. The power gain, a_1, and the antenna gain, a_2, may easily be determined from a knowledge of the transmitter power and the polar diagram of the antenna.

The terms a_3 to a_8 may be described as " loss factors ". Of these terms, spatial attenuation, a_3, and non-deviative absorption a_4, are dealt with separately in §§ 5.2 and 5.3.

Losses due to deviative absorption, a_5, are important only when the frequency is close to the MUF for E- and F-layer propagation (within 20% of the MUF) and, in such cases, an appropriate correction factor must be considered. This factor is ignored in normal calculations. However, on the basis of measurements of ionospheric absorption at night, a_5 is taken as 2·5 dB in all cases for the calculation of night-time field strength.

In multi-hop transmissions, the appropriate value of the ground-reflection loss, a_6, depending on the particular terrain, must be taken into account.

The factor, a_7, arises from the elliptical polarization of a radio-wave propagated through the ionosphere and the field strength measured with a linearly polarized antenna is less than the maximum value of the rotating vector.

Following the C.R.P.L., a_7 has been taken as 3 dB.

It is recognized that partial reflections from Es result in some losses, a_8. However, in any practical method of calculation, it is difficult to take this factor into account. Similarly, it is also difficult to take into account any losses when spread-F is present.

5.2 *Spatial attenuation (a_3)*

The attenuation suffered by a radio-wave due to spreading is directly proportional to the distance. In ionospheric propagation, some additional factors come into play. Due to the concavity of the reflecting layers, a decrease in the attenuation, as compared with the value given by the law usually assumed, may be expected, especially at long distances. A detailed study of this phenomenon was carried out by Rawer. According to him, this focusing effect considerably reduces the spatial attenuation, at distances greater than about 1500 km. Since the distances involved in tropical broadcasting circuits are usually less than 1500 km, it is not possible, at this stage, to verify the presence and degree of the focusing effect.

5.3 *Non-deviative absorption (a_4)*

During the day, non-deviative absorption is one of the most important factors to be considered in calculating the sky-wave field strength.

Non-deviative absorption:

$$a_4 = [635\, n\, (1 + 0{\cdot}0017\, \overline{R}) \sec \varphi] \,/\, (f \pm f_L)^2\, [\mathrm{Ch}\,(R, \chi)]^{0{\cdot}77}\ \mathrm{(dB)} \qquad (6)$$

where

- n : number of hops,
- $\overline{R}$: twelve months running average of sunspot number,
- φ : angle of incidence of the wave at the absorbing layer,
- f : frequency of the radio-wave,
- f_L : longitudinal component of the gyromagnetic frequency,
- $\mathrm{Ch}(R, \chi)$: Chapman function for a scale height of 5·8 km, for $\chi \leqslant 80°$, $\mathrm{Ch}(R, \chi) \approx \sec \chi$,
- $+, -$: signs correspond to the ordinary and extraordinary ray respectively.

The seasonal variation of absorption has not been found to be of much consequence. The value for f_L may, for all practical purposes, be taken as unity.

5.4 To facilitate the rapid evaluation of field strength, a set of ten curves has been provided. By progressive substitution, the field strength for any circuit by any mode can be directly read. In Fig. 5, the values of cos χ have been given, for different latitudes at various local times. Fig. 6 provides an intermediate parameter X corresponding to the value cos χ read and the sunspot number $\overline{R}$.

Here

$$X = (1 + 0{\cdot}0017\, \overline{R}) \,/\, [\mathrm{Ch}(R, \chi)]^{0{\cdot}77}$$

Fig. 7 gives absorption, Y, at vertical incidence, as a function of values of X for various frequencies.

Fig. 8 shows the angles of radiation as a function of distance of the receiving point for various layer heights.

Fig. 9 gives the absorption for 1-hop modes, Z, at oblique incidence.

Fig. 10 gives the unabsorbed field intensity, F_a, for various distances ($F_a = F_0 - a_3 - a_7$).

Fig. 11 shows the ground losses for various angles of radiation, soil conductivity and frequency.

For higher-order modes, the distance of transmission is taken as $1/n$ of the actual distance and the same curves are used to calculate the values of unabsorbed field intensity, non-deviative absorption and ground losses.

F_a = value of unabsorbed field (read for 1 hop for $(1/n)$th distance) minus 20 log n,

$a_4 = n \times$ value of losses (read for 1 hop for $(1/n)$th distance),

$a_6 = (n - 1) \times$ value of a_6 loss (read for 1 hop for $(1/n)$th distance).

This assumes that the ionospheric conditions are uniform throughout the path. When the path is long, this assumption is not valid. The value of a_4 is then found by taking the values of the losses for each hop and adding them.

5.5 *Consideration of the mode of propagation*

By following the procedure outlined in the previous sections, it would be possible to calculate the field strength that may be expected, if the propagation is by any particular mode (such as 1-F, 1-E, 2-F, 2-E, etc.). To estimate the actual field strength for any particular circuit, it is necessary to determine the predominant mode of propagation. The maximum usable frequency for transmission by the E layer can be read from Figs. 12 and 13. The possibility of sustaining any mode by the F layer can be examined by reference to Fig. 14, which gives the MUF factor for transmission by the F layer for various distances and layer heights. It is also necessary, in this case, to examine the possibility of cut-off by any lower layer (see § 5.6). The field strengths due to a few plausible modes are calculated. The actual field strength would be that due to the mode of propagation that gives the highest field strength. However, occasionally, the field-strength due to two modes or more may be found to be nearly equal. In such cases, the r.m.s. value of these signals is taken as the actual estimated value of the field strength.

5.6 *Cut-off frequency for the E layer*

As mentioned in § 5.5, it is essential to predict the cut-off frequency for the E layer to determine the active modes of propagation. On the basis of analysis of data for the E-layer critical frequency over a complete sunspot cycle for a number of stations, a formula for the calculation of foE has been developed by All India Radio, which has shown a very good correlation with observed results. This formula has been used for the preparation of curves for the calculation of cut-off frequency for the E region.

The formula for foE is given by:

$$\text{foE} = [3{\cdot}42\,(1{\cdot}0015\,\bar{R})\,S]\;/\;[\text{Ch}(a, \chi)]^{\,0{\cdot}34}$$

where

foE = critical frequency of E layer for the ordinary component of the ray,

$\bar{R}$ = twelve month running average of sunspot number,

S = seasonal variation factor ($\approx 1{\cdot}0$)
($S = 1{\cdot}0$ in summer and at the equinoxes and $1{\cdot}03$ in winter),

$\text{Ch}(a, \chi)$ = Chapman function for a scale height of 10 km,
when $\chi \leqslant 85°$, $\text{Ch}(a, \chi) \approx \sec \chi$.

Fig. 12 gives the values of E-layer critical frequencies (foE) for different values of cos χ and sunspot number $\bar{R}$. Fig. 13 gives the maximum usable frequency by E-layer transmission for various angles of radiation and E-layer critical frequencies. This also represents the frequency below which transmission by the F layer is precluded (E-layer cut-off frequency for the angle of radiation).

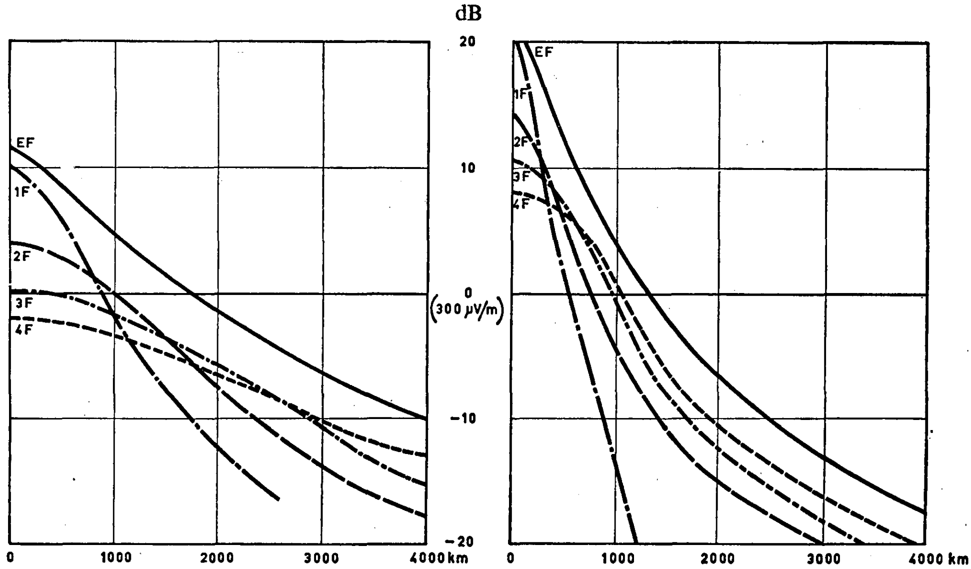
5.7 *Comparison between calculated and measured values of field strength*

The measured values of field strength have been compared with the calculated values obtained by C.R.P.L., S.P.I.M., RPU-9, D.S.I.R. and the A.I.R. methods. It has been observed that the values calculated by the A.I.R. and D.S.I.R. methods are in close agreement with measured values of the field strength, whereas the deviation is considerable for the other three methods, namely C.R.P.L. S.P.I.M., and RPU-9.

6. Doc. XII/18 (United Kingdom), Bad Kreuznach, 1962

For a period of approximately twelve months, field-strength recordings of seven transmissions were made by the D.S.I.R. at Singapore and the monthly-median field strength for each hour has been determined. The curves of field strength against time for all stations show the same general characteristic, namely, a rise in field strength from the commencement of transmission in the early evening and a levelling off from about 2000 hours LMT. At Saigon, which operated for a large part of the day, the field-strength time curves show that this rise in strength begins at about 1300 hours LMT, when the absorption in the ionosphere begins to decrease.

6.1 Calculations of field strength were made by the C.R.P.L. and RPU-9 methods. While both methods, generally speaking, give curves following closely the shape of the measured curves, there are differences of up to 6 dB in the two field strengths. C.R.P.L. values are, in general, lower than those measured, while the RPU-9 values are higher.



Distance

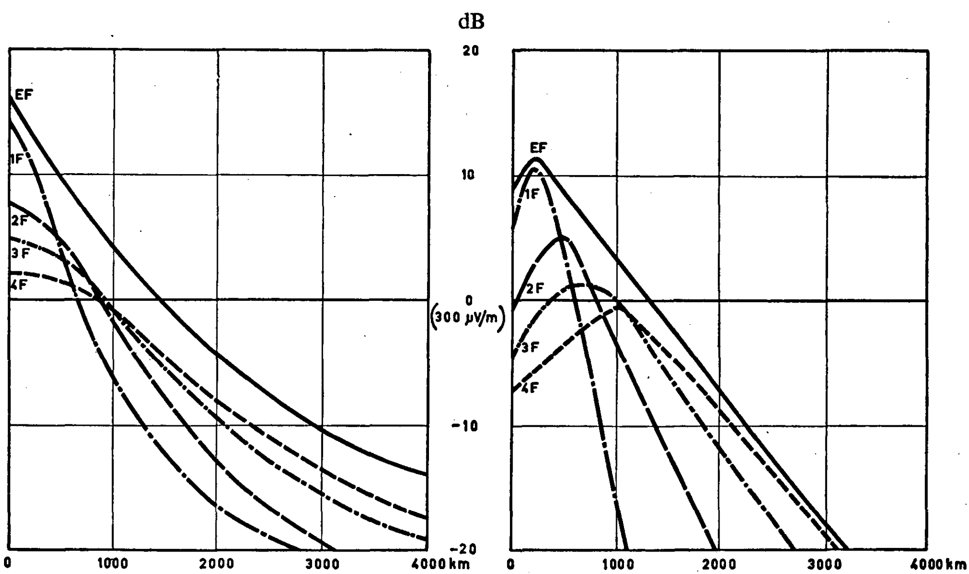
(a) A simple half-wave antenna: $H = 0{\cdot}25\ \lambda$

Distance

(b) Four-slot antenna: $H = 0{\cdot}25\ \lambda$

FIGURE 1

Influence of antenna gain for radiation towards the vertical—Dakar, at 2000 hrs LMT



Distance

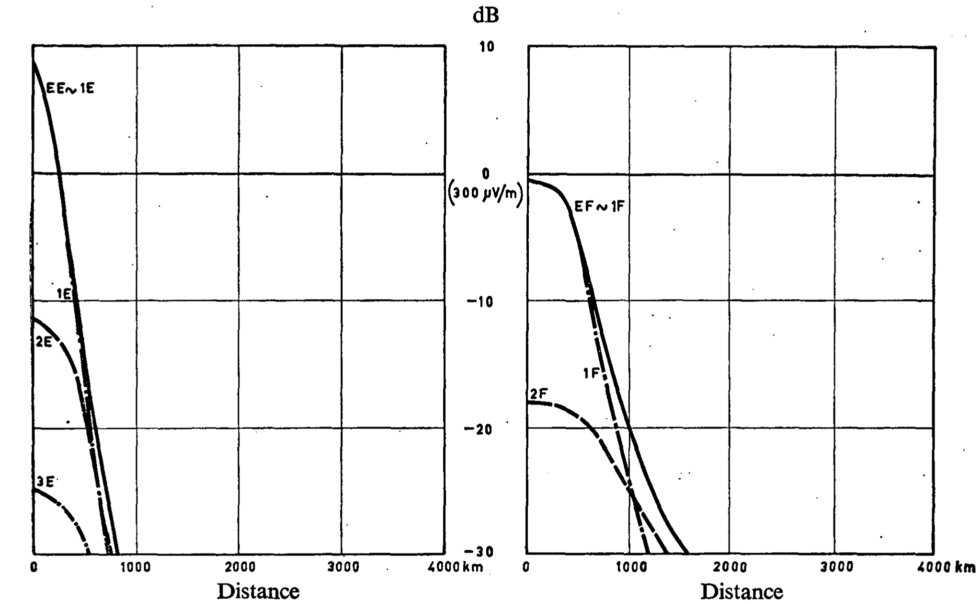
(a) Single-slot antenna—vertical transmission
$H = 0{\cdot}25\ \lambda$

Distance

(b) Single-slot antenna—oblique transmission
$H = 0{\cdot}4\ \lambda$

FIGURE 2

The effect of angle of elevation for narrow-beam antennae—Dakar, 2000 hrs LMT



(a) E-layer reflection

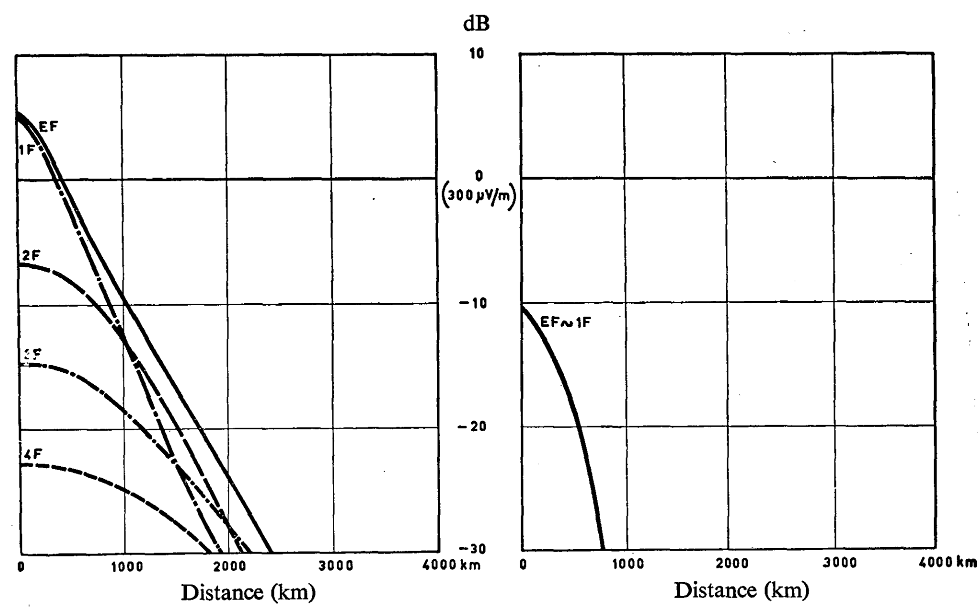
(b) F-layer reflection

FIGURE 3

Comparison between E-layer and F-layer reflections

Dakar, 5 MHz, June, $\overline{R}$ = 10; 0800 hrs LMT

Comparable absorption for a half-wave antenna $H = 0{\cdot}25\ \lambda$



(a) Low absorption—Dakar, June, $\overline{R}$ = 10; 0800 hrs LMT; 7 MHz

(b) Heavy absorption—Dakar, June, $\overline{R}$ = 150; 1200 hrs LMT; 7 MHz

FIGURE 4

The effect of absorption—half-wave antenna, $H = 0{\cdot}25\ \lambda$

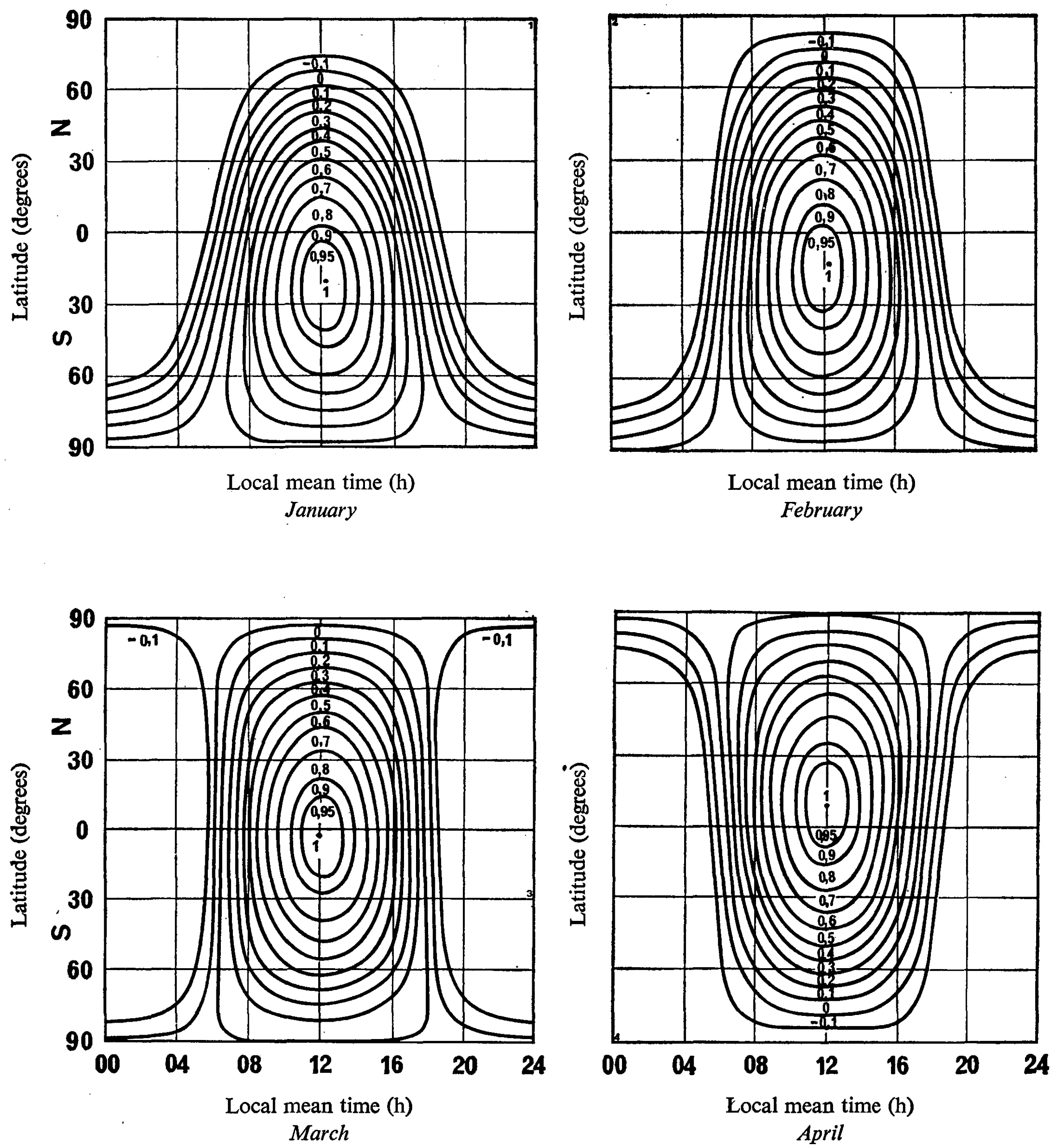


FIGURE 5a

Values of cos χ (January to April)

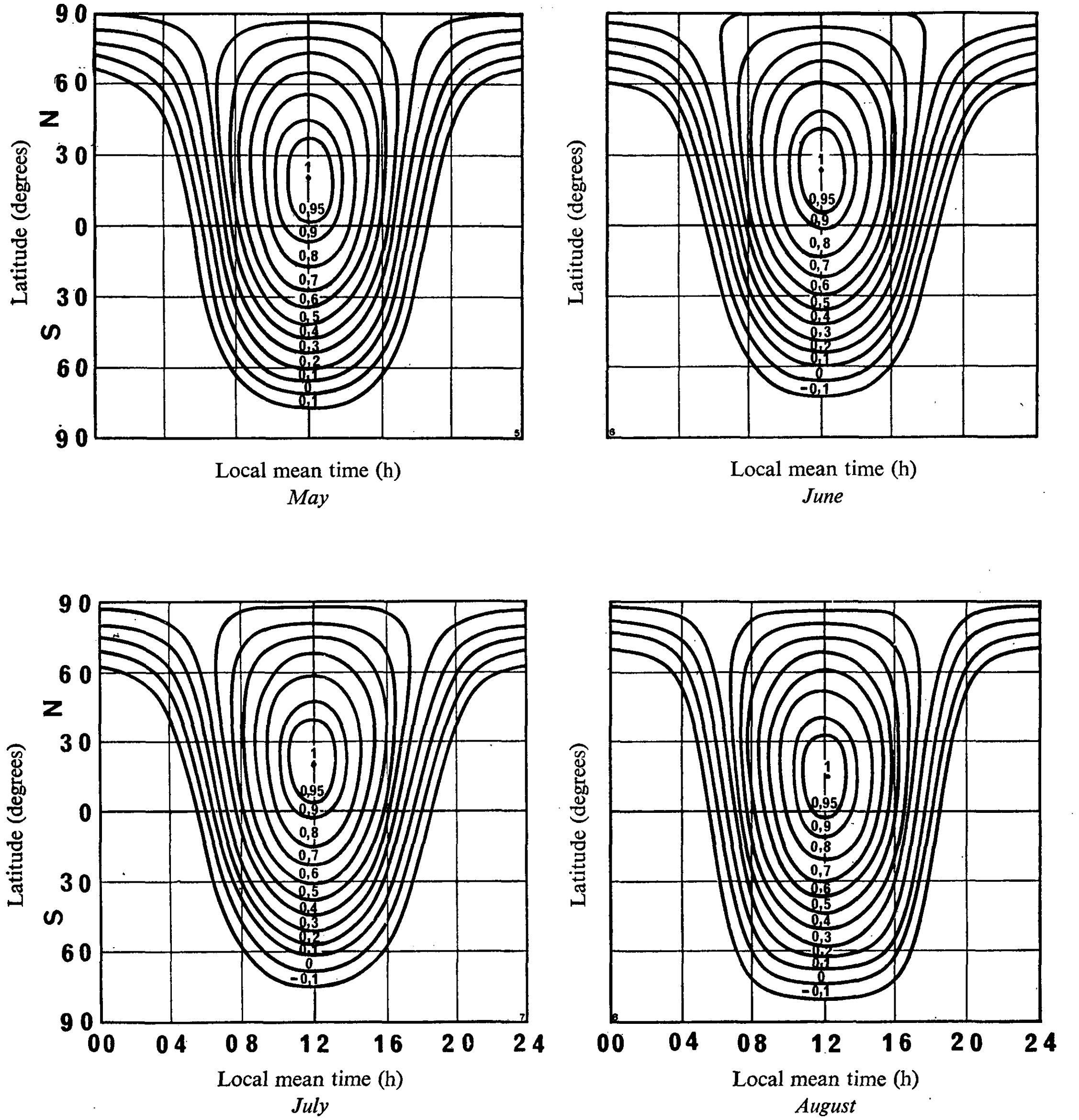


FIGURE 5*b*

Values of cos χ (May to August)

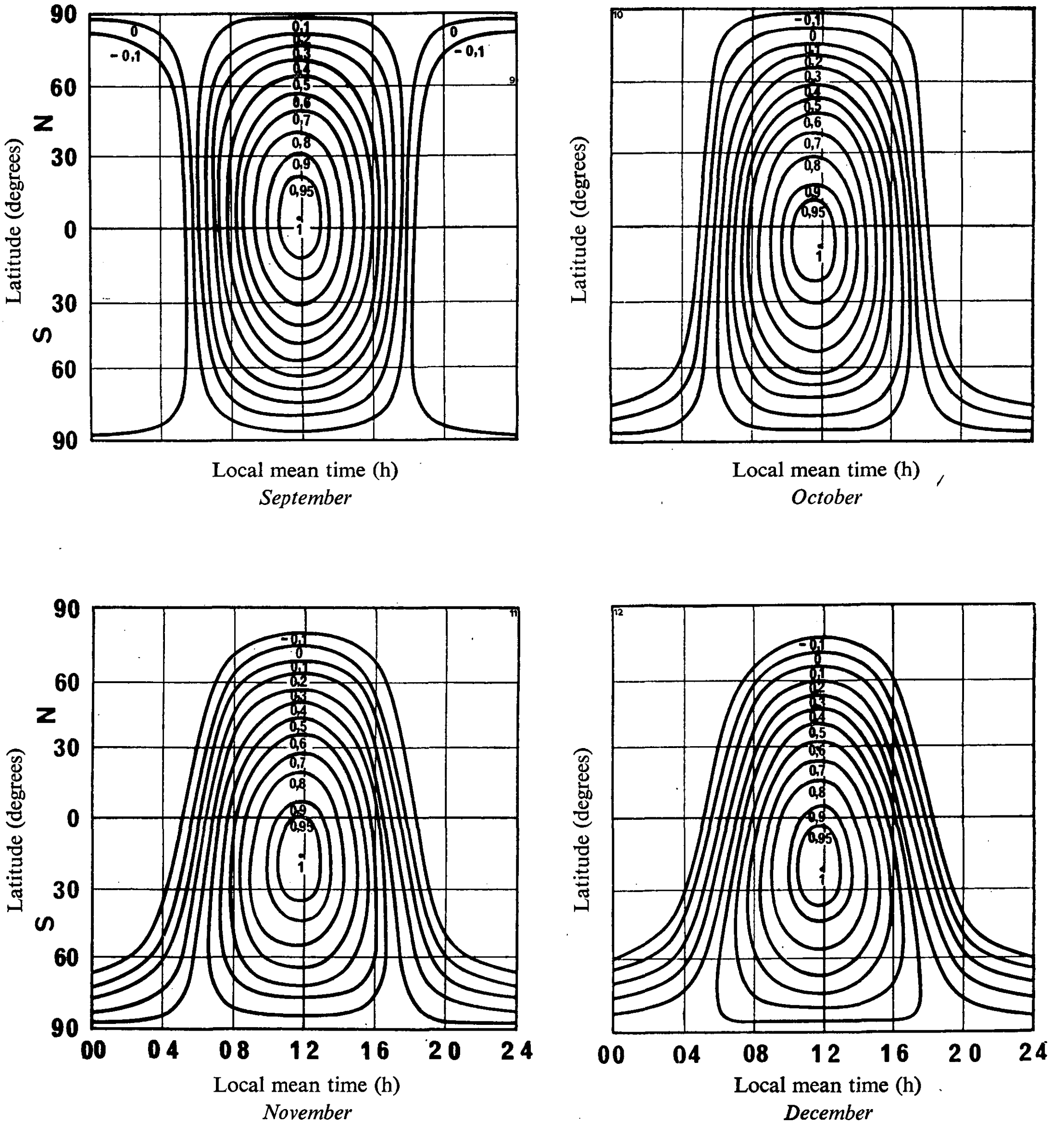


FIGURE 5c

Values of cos χ (September to December)

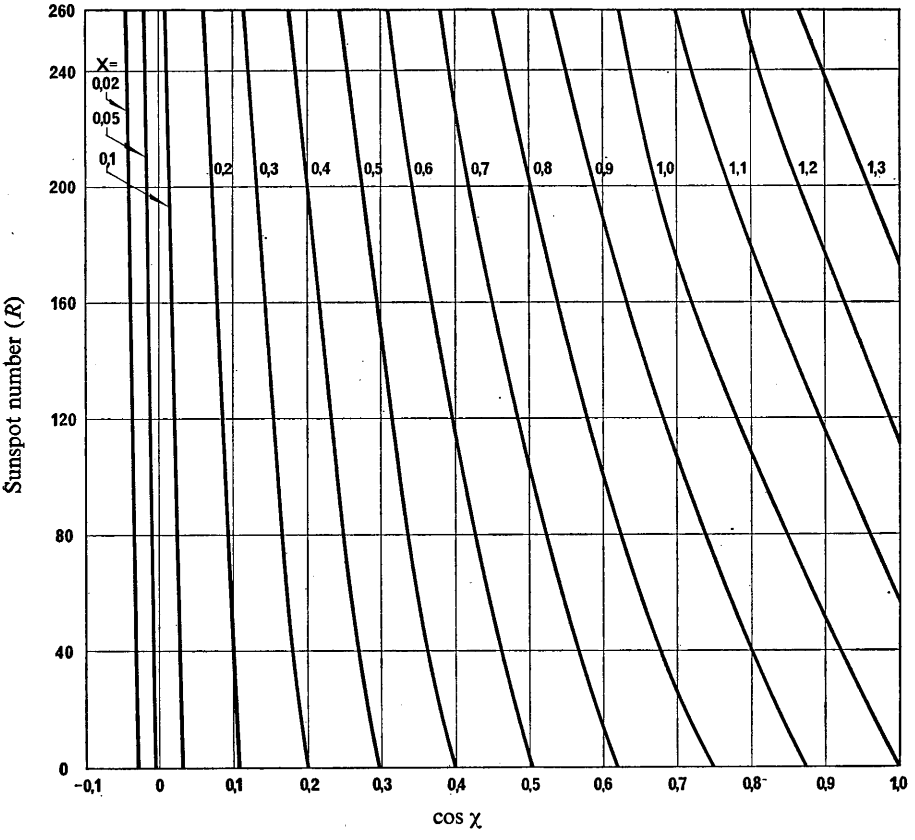


FIGURE 6

Values of X for different sunspot numbers and values of cos χ
(The values of *X* are indicated on the curves)

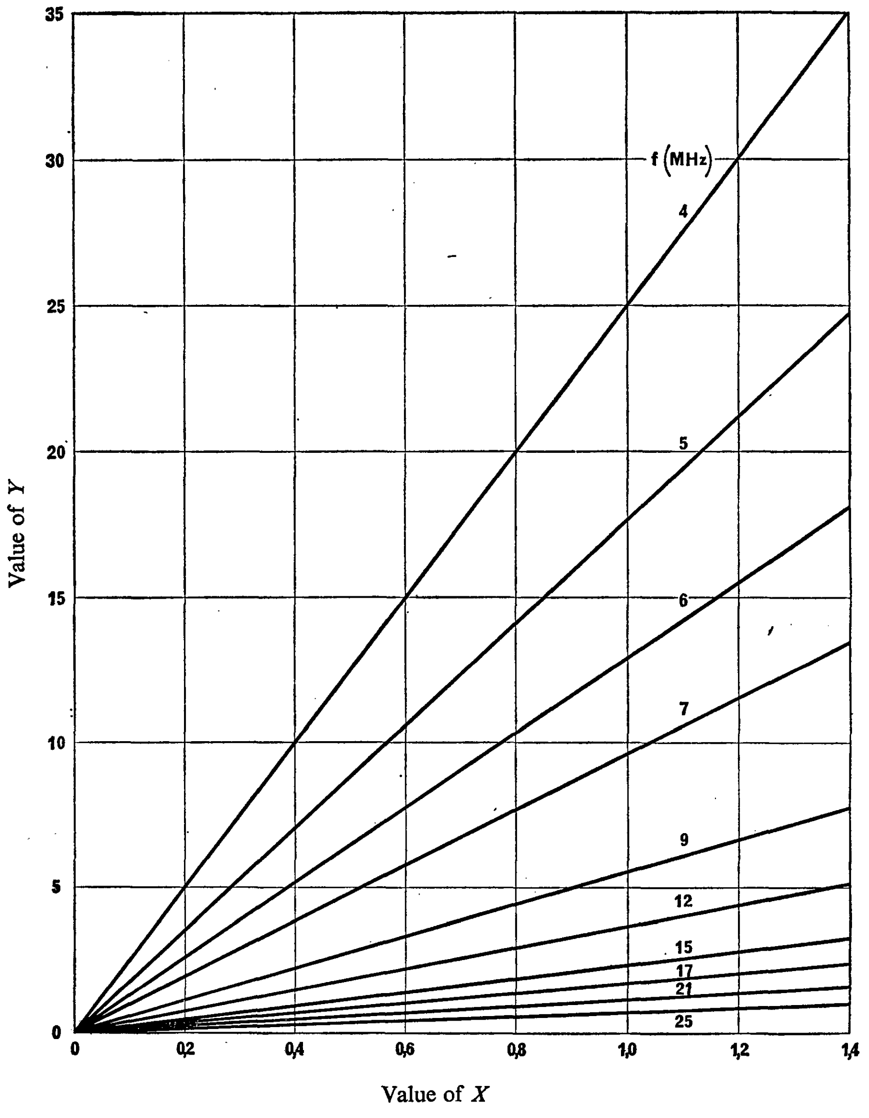


FIGURE 7

Value of Y as a function of X with the band, f, as a parameter

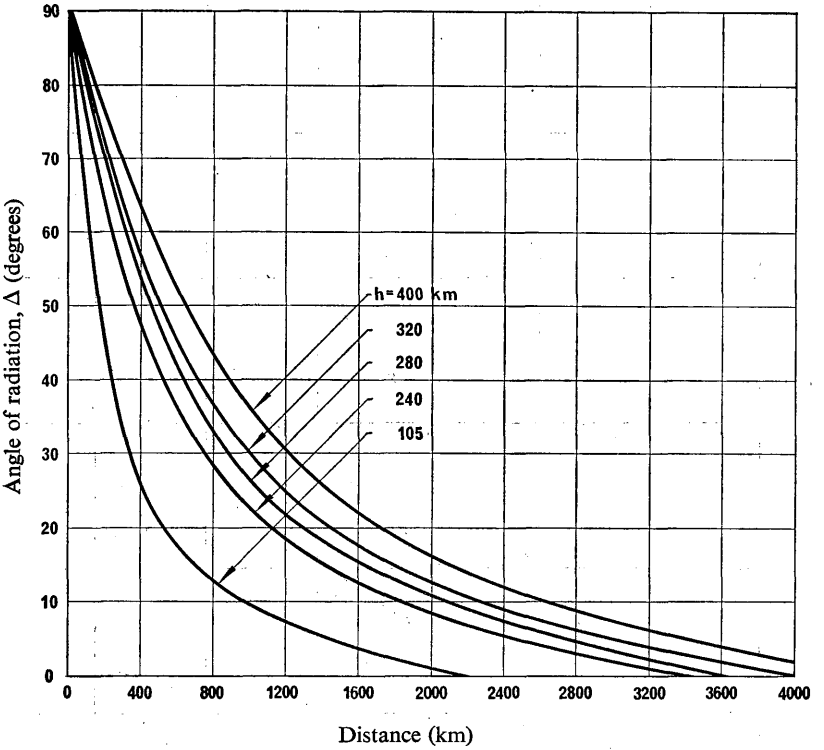


FIGURE 8

Angle of radiation, Δ, as a function of distance, with height of layer, h, as a parameter

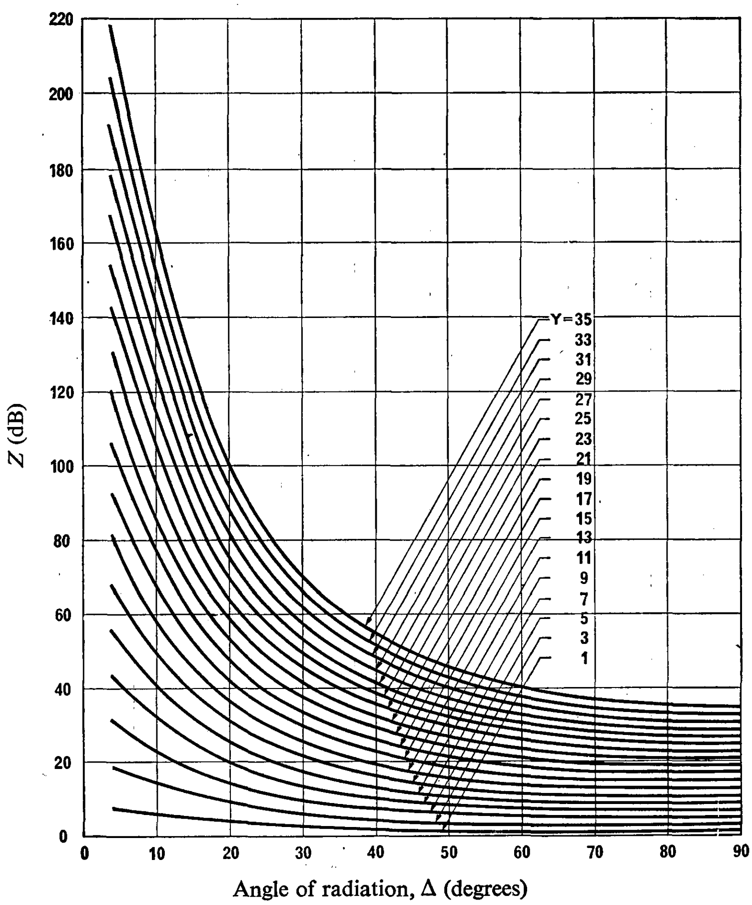


FIGURE 9

Value of Z as a function of the angle of radiation, Δ, with Y as a parameter

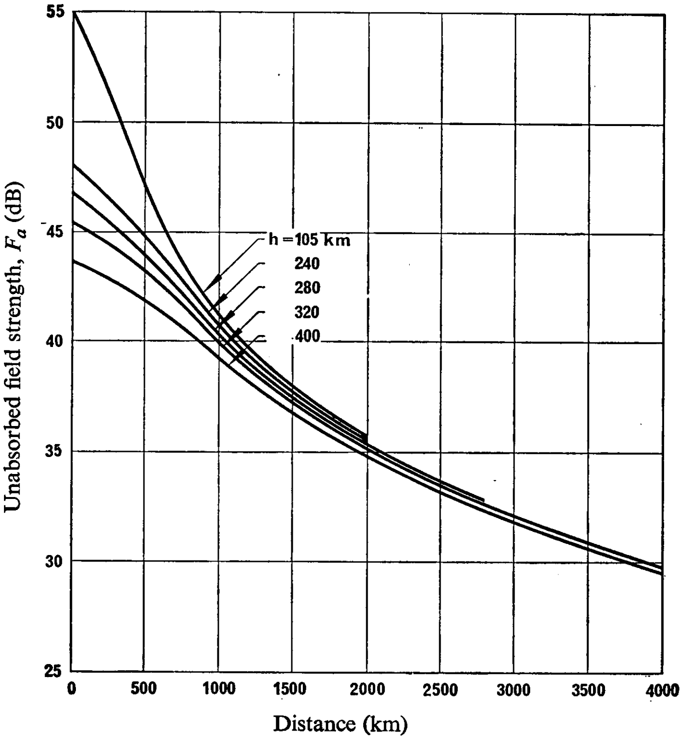


FIGURE 10

Unabsorbed field strength, F_a, as a function of distance, with height of layer, h, as a parameter

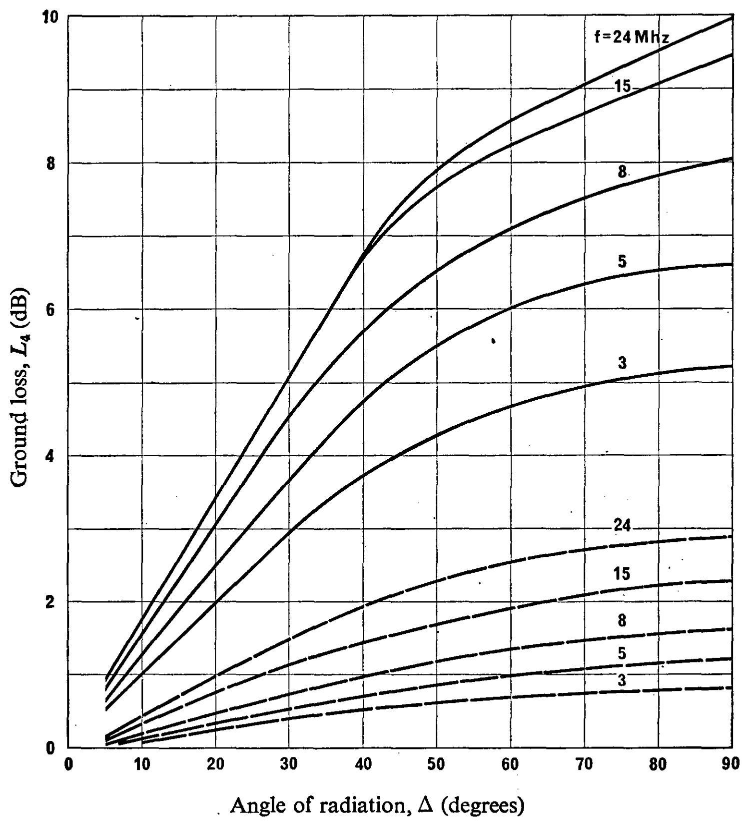


FIGURE 11

Ground loss, L_4, as a function of angle of radiation, for various types of soil, with frequency, f(MHz) as a parameter

——————— : good soil, $\sigma = 3 \times 10^{-13}$ e.m.u.

– – – – – – – : poor soil, $\sigma = 1 \times 10^{-14}$ e.m.u.

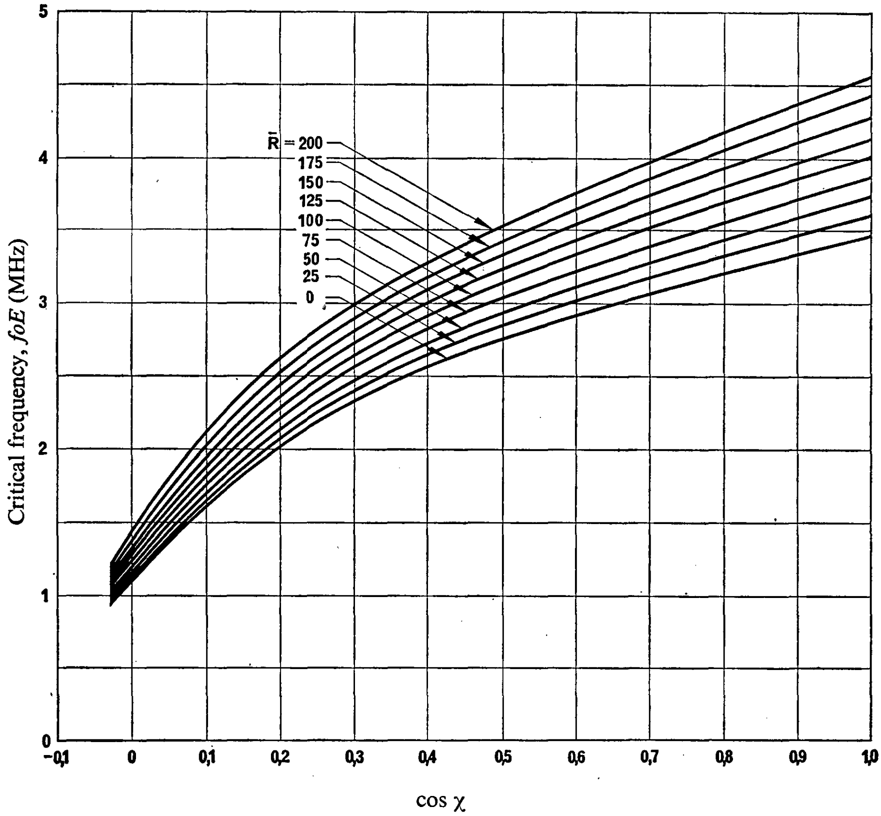


FIGURE 12

Critical frequency, foE, as a function of cos χ, with $\overline{R}$ as a parameter

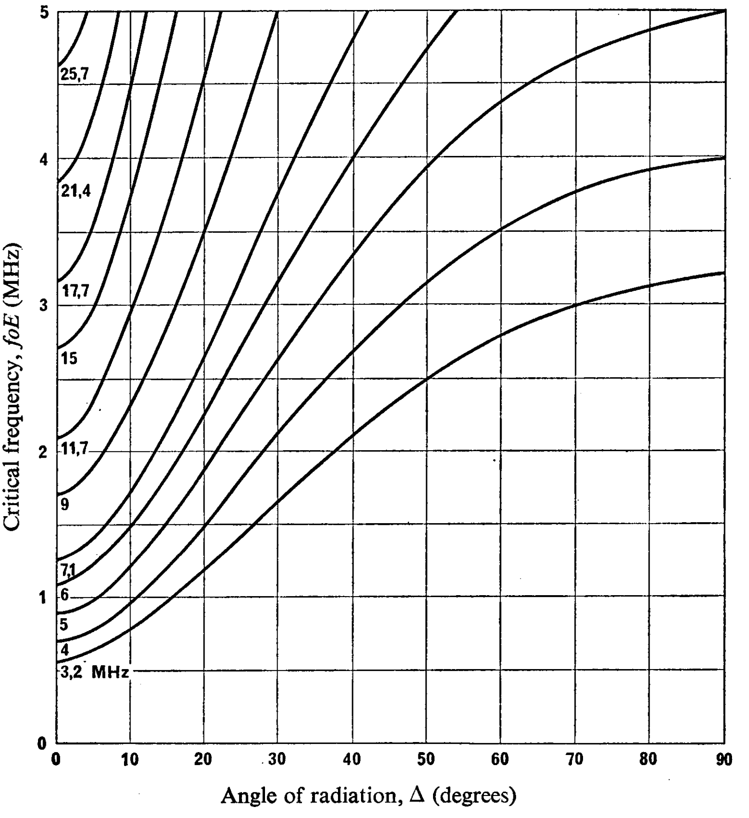


FIGURE 13

Values of E-layer MUF for different values of foE and angle of radiation
(The values of the MUF (MHz) are indicated on the curves)

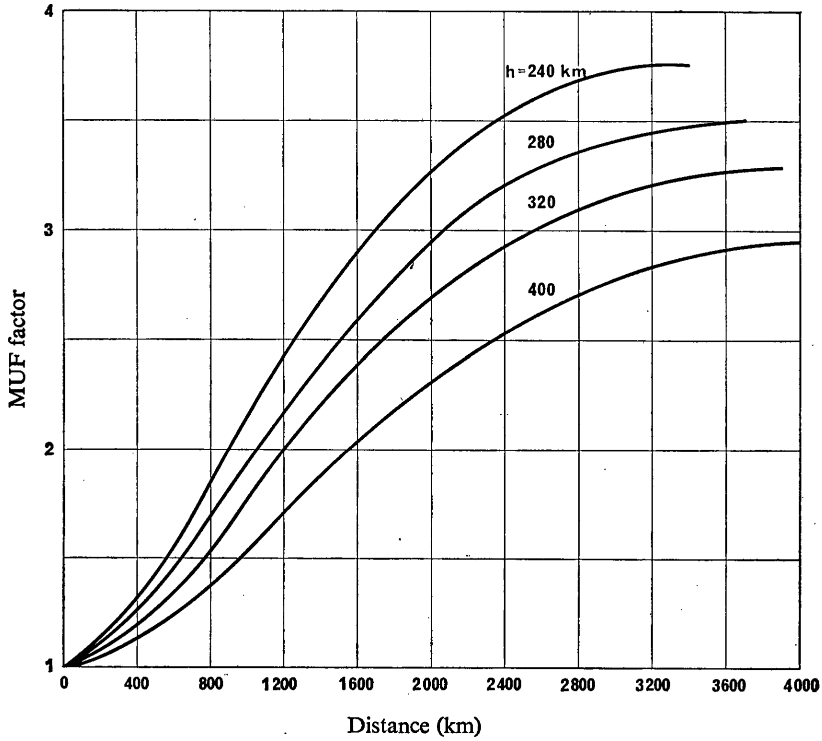


FIGURE 14

MUF factor as a function of distance with height of layer, h, as a parameter

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REPORT 472 *

USE OF SINGLE-SIDEBAND RECEPTION FOR MINIMIZING THE EFFECTS OF FADING FOR RE-BROADCAST APPLICATIONS WITHIN THE TROPICAL ZONE

(Study Programme 33A/10)

(1970)

1. Introduction

This Report summarizes the results of the preliminary studies carried out to assess the improvement in reception of broadcast emissions in band 7 (HF) when single-sideband receivers are used.

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* This Report was adopted unanimously.

2. Doc. XII/5 (India), 1966-1969

This document gives the results of preliminary listening tests on the improvement in quality of broadcast spoken-word programmes in band 7 (HF) for re-broadcasting purposes, by receiving the double-sideband emissions on a single-sideband receiver. A commercially-built single-sideband adaptor was used, together with a standard band 7 (HF) communication receiver for these tests. The single-sideband adaptor had the following main characteristics:

— sharply tuned bandpass filters to select either the upper or lower sideband of the emissions;
— carrier rejection filter (30 dB);
— stable, tunable local oscillator for carrier re-insertion;
— automatic frequency control of the local carrier re-insertion oscillator;
— oscilloscope indicator for correct tuning.

The listening tests indicate that in the presence of surge and flutter fading, reception is worst using double-sideband reception with automatic gain control; perceptible improvement is observed in the reception of surging double-sideband signal without automatic gain control in the receiver. When " surge " and " flutter " fading are acute, a noticeable improvement is obtained by the use of single-sideband reception, even with automatic gain control. It would appear that reception on a single-sideband receiver with automatic gain control can give acceptable quality of the spoken word when surge and flutter fading are present.

While these preliminary studies have indicated the possibility of reducing the effects of surge and flutter fading by using single-sideband reception, there is a need for further detailed and extended tests, both subjective and objective, to assess the extent of improvement that could be achieved and the instrumentation needed.

3. Doc. XII/7 (Federal Republic of Germany), 1966-1969

This document discusses the technical implications of this mode of operation. It explains the effect of selective fading on both double-sideband and single-sideband emissions. For double-sideband emissions, selective fading near the carrier frequency causes an apparent increase in the depth of modulation, which in turn gives rise to distortion, as soon as the carrier voltage is reduced below the value of the sum of the sideband voltages. Moreover, the amplitudes of the low frequencies of the information are attenuated. Hence, the dynamic range and tonal quality of the signal are changed. For single-sideband emissions the interfering effect of selective fading of the carrier is completely eliminated. Compared with the amplitude of the sideband, the amplitude of the carrier re-inserted in the receiver is very high and causes the phase modulation of the sum vector to be reduced to a very low level. Consequently, the signal is not distorted by carrier fading.

Selective fading in the sideband changes, however, the tonal quality of the signal. The effect is noticeable when significant information content, such as the low frequencies of a musical programme, is affected by fading. This could be remedied by frequency diversity reception of the two sidebands. However, this method fails if one sideband is subjected to interference from another transmitter. (On the other hand, it is possible to avoid the interfering transmitter by a manual change-over to the undisturbed sideband, but this method cannot be applied to double-sideband reception.) In this case, diversity reception is only possible when space or polarization diversity is applied to the undisturbed sideband. This method requires more complex equipment for various reasons, *inter alia,* because amplitude changes must not be audible during diversity switching.

Doc. XII/7 further gives a description of an experimental comparison between double- and single-sideband reception. At the Interim Meeting, the delegate of the Federal Republic of Germany gave a demonstration.

A double-sideband emission in band 7 (HF) (6 MHz band) was received on a receiver with three outputs:

— double-sideband,

— single-sideband,

— field strength.

The signals from the first two outputs were recorded simultaneously on the two tracks of a tape-recorder while the signal from the third output was recorded on a paper chart-recorder. The counter on the tape-recorder was used to mark the paper-recording simultaneously. Switching from track 1 to track 2 and vice-versa of the tape-recorder allowed immediate comparison between the effects of fading on double-sideband and single-sideband reception. Different types of fading were recorded and could be compared with one another.

Study Group XII* agreed unanimously that single-sideband reception gave a significant improvement in the quality of reception;

The Study Group concluded that tests with single-sideband receivers for re-broadcast purposes have shown that:

3.1 the use of a single-sideband receiver provides a noticeable improvement in the quality of reception;

3.2 the observed effects are subjective and are therefore not open to exact measurement. The introduction of a subjective scale is necessary;

3.3 the characteristics of the single-sideband receiver affect the degree of improvement observable. A fairly high-class receiver is necessary to make good use of the possibilities. In particular:

3.3.1 the selectivity characteristic must be very sharp with steep flanks;

3.3.2 the frequency stability of the receiver must be high necessitating the provision of a " lock-in " circuit for automatic synchronization of the local oscillator with the frequency to be received;

3.3.3 a built-in oscilloscope is most useful for tuning a receiver of this type.

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* At the XIIth Plenary Assembly, Study Group XII (Broadcasting in the Tropical Zone) was incorporated in Study Group 10 (Sound broadcasting).

QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS

(STUDY GROUP 10)

STUDY PROGRAMME 1A-1/10 *

STANDARDS OF SOUND RECORDING FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES

The C.C.I.R. (1951 – 1953 – 1959 – 1970)

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the possibility of adopting, for the international exchange of sound programmes on magnetic tape, a speed of 9·525 cm/s (3·75 in./s), and the determination of the standards to be used, especially the reproducing characteristics;
2. investigation of methods for measuring slow speed fluctuation ($<$0·2 Hz) and rapid speed fluctuation ($>$200 Hz) and of permissible values of these; investigation of permissible limits for wow and flutter measured in accordance with Recommendation 409-2;
3. further investigation of the technique of sound recording to extend and improve the recommendations already made and to reduce the tolerances.

STUDY PROGRAMME 2A/10 *

MEASUREMENT OF AUDIO-FREQUENCY NOISE FOR BROADCASTING AND IN SOUND RECORDING SYSTEMS

(Report 292-2)

The C.C.I.R., (1959)

CONSIDERING

that no methods exist for measuring noise in the audio-frequency channels of broadcasting systems and in sound recording systems, which provide satisfactory agreement with subjective assessments;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. what type of measuring set (mean, r.m.s. or peak) should be used for the measurement of noise;
2. what characteristics should be recommended for these measuring sets?

Note. — Study of §§ 1 and 2 should be made, with reference to the measurement of noise with and without programme modulation (modulation noise in magnetic recording).

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* This Study Programme does not arise from any Question under study.

QUESTION 4/10

DETERMINATION OF THE SUBJECTIVE LOUDNESS OF A BROADCASTING PROGRAMME

The C.C.I.R., (1965)

CONSIDERING

(a) that existing specifications and techniques for the determination of sound modulation levels in broadcasting are generally based on peak or quasi-peak programme levels;

(b) that neither true peak nor quasi-peak programme levels are necessarily indicative of subjective loudness;

(c) that it may be advantageous to take subjective loudness into account in the determination of programme levels;

(d) that Report 292-2 has suggested the possibility of a study of the problem of the measurement and control of dynamic range of sound programmes;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the effects of amplitude, frequency range and other factors on loudness;

2. what techniques may be used to measure the subjective loudness of programme material in broadcasting;

3. what degree of accuracy is obtainable with each;

4. what characteristics should a meter possess to measure subjective loudness?

STUDY PROGRAMME 4A/10

MEASUREMENT, INDICATION AND CONTROL OF THE SUBJECTIVE LOUDNESS OF A BROADCAST PROGRAMME

The C.C.I.R., (1970)

CONSIDERING

(a) that the problems of measurement, indication and control of the subjective loudness of a broadcasting programme require thorough investigation and study, especially with regard to the parameters to be found in the relationship between music and voice announcements;

(b) that existing specifications and techniques for the determination of programme levels in broadcasting are generally based on peak or quasi-peak readings;

(c) that neither true peak nor quasi-peak programme levels are necessarily indicative of subjective loudness;

(d) that it is considered advantageous to take subjective loudness into account in the determination of modulation levels;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the effects of amplitude, frequency range, signal duration, strident delivery and the psychological and physiological reaction of a representative cross-section of listeners to these and other factors in subjective loudness:

1.1 the parameters which it is essential or desirable to check during transmission to establish the subjective loudness of different types of programmes;

1.2 the methods to be used to determine the effect of these parameters on subjective loudness;

1.3 the results to be obtained from the use of these methods, and how they are expressed;

1.4 in television transmission, the effect of the associated picture;

2. indication of subjective loudness on an instantaneous and continuous basis:

2.1 the techniques or instrumentation which may be used to measure the subjective loudness of programme material in broadcasting;

2.2 the degree of accuracy obtainable with each;

2.3 if a meter is used, the characteristics it should possess to measure subjective loudness;

2.4 the point in the transmission chain where the measuring instrument should be connected;

3. control of loudness for optimum balance of subjective parameters of different types of programmes:

3.1 the elements in the transmission chain which may affect the control of subjective loudness;

3.2 the point in the transmission chain where the loudness control should be connected;

3.3 the element(s) which should be varied to balance the subjective loudness of different programmes;

3.4 the method(s) which may be used for control;

3.5 the effect of existing automatic gain control devices on programmes controlled for subjective loudness.

Note. — As an aid in comparing the results of studies it is suggested that Administrations should report programme levels in terms of peak values measured with one of the peak meters described in Report 292-2. The type used should be specified.

QUESTION 11-1/10

BROADCASTING IN BAND 6 (MF)

Reduction of sky-wave field strength

The C.C.I.R., (1966 - 1970)

CONSIDERING

(a) that, under certain circumstances, a substantial reduction in the field strength of sky-wave transmission in band 6 (MF) is produced by transmitting an elliptically polarized wave in a manner referred to as orthogonal transmission (see Note);

(b) that this type of transmission is expected to reduce sky-wave interference and to extend the primary service area of broadcasting stations restricted by fading, due to such interference;

(c) that these improvements may be produced without altering the horizontal radiation pattern of the transmitting antenna;

(d) that more transmitter power than that at present employed at night is required to operate this system;

Note. — Orthogonal transmission refers to a system in which the transmitting antenna radiates waves that are polarized for maximum absorption (see Report 264-1, § 3.3, Vol. II).

UNANIMOUSLY DECIDES that the following question should be studied:

1. what improvement in reception can be obtained with orthogonal transmission, and to what extent does it depend on:

1.1 transmission frequency relative to the gyro-frequency;

1.2 magnetic dip between the mid-point of the path and the transmitter;

1.3 magnetic bearing of the path;

1.4 the distance;

2. what types of transmitting antennae can be used;

3. what is the effect of time of day, season and sunspot cycle?

QUESTION 13/10

BROADCASTING IN BANDS 5 (LF) AND 6 (MF)

High-efficiency transmitting antennae

The C.C.I.R., (1963)

CONSIDERING

(a) that there is a general tendency to increase the size of the service area of broadcasting transmitters operating in bands 5 (LF) and 6 (MF) by increasing the transmitter power;

(b) that, especially with high-power transmitters, it is preferable to increase the size of the service area by the use of high-efficiency antennae, especially when the size of the service area is limited by interference between the sky- and the ground-waves;

UNANIMOUSLY DECIDES that the following question should be studied:

what types of antenna can be used in practice, to increase the area served either by the ground wave or the sky wave, taking into account the effects of reflections from the E and F layers?

QUESTION 14/10

BROADCASTING IN BAND 7 (HF)

Directional antenna systems

(1948)

For the following Question, it will be appropriate to organize the compilation of statistical measured results from antennae of different types in various parts of the world, in respect of the signal laid down by the main beam and subsidiary lobes, and the amount of scattering in unwanted directions.

The C.C.I.R.

UNANIMOUSLY DECIDES that the following question should be studied:

what are the methods by which the formation of strong subsidiary lobes can be avoided, particularly when the directional antenna systems are fed asymmetrically to produce a slew of the main beam?

Note. — The reasons which justify this Question are given in the Annex.

ANNEX

The characteristics of directional antenna systems, used in broadcasting, have been completely studied from theoretical aspects, and a number of experimental investigations have been undertaken by various bodies on the actual measured performance (see the Bibliography).

With a suitably designed antenna, the power radiated in unwanted directions can be reduced to a small proportion of the power radiated in the wanted direction. An antenna system, with a reflector having an aperture of two wavelengths, should have a radiation at 25° off the main beam, reduced 16 dB below the main radiation field. At 40° off the main beam, the radiation should be reduced to 35 dB below the main radiation path. Tests have been made as to the actual reception at distant points at places which are off the main radiation beam. These show, however, that the field at such reception points is often in excess of the expected field predicted from the power radiated in the given direction.

These abnormal signal strengths presumably result from a field which is a combination of a direct radiation in the given direction, and indirect radiation due to scattering of the main beam on reflection. Measurements of this phenomenon would clearly take a considerable time and could only be properly evaluated on a statistical basis. It appears possible that the limitation to frequency sharing may be the scattering of the main beam of radiation.

It will, however, always be of utility to reduce the power radiated in unwanted directions and particularly in the subsidiary lobes of an antenna system.

Further study of this question is recommended and, in particular, it is recommended that attention be given to the development of methods of avoiding the production of subsidiary radiation lobes when a directional antenna is fed asymmetrically to produce a slew of the main lobe of radiation.

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5. HACKE, J. E. Jr. and WAYNICK, A. H. *Restricted range sky wave transmission*. Elec. Eng. Dept., Pennsylvania State College, Pa., U.S.A.

STUDY PROGRAMME 14A/10

BROADCASTING IN BAND 7 (HF)

Directional antenna systems

(Recommendation 80)

The C.C.I.R., (1956)

CONSIDERING

(a) the development in the use of highly directional antenna systems for broadcasting in band 7 (HF);

(b) the need to share frequencies wherever possible, to allow the most efficient use of the broadcasting bands;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the extent to which the theoretical protection can be obtained in practice when using the usual types of directional broadcasting transmitting antennae.

Note 1. — It is suggested that actual field-strength measurements should be obtained to verify the nominal gain in the main beam and the validity of Recommendation 80.

Note 2. — Tests should be arranged in such a way as to eliminate to the greatest possible extent the effects of changing ionospheric conditions.

QUESTION 15/10

STEREOPHONIC BROADCASTING

The C.C.I.R., (1959)

CONSIDERING

(a) that stereophonic recording of sound on both disc and magnetic tape is already becoming well established in the industry and such discs and tapes are already on sale to the public in some countries;

(b) that experimental transmissions of stereophonic sound programmes have already been made by broadcasting stations in a number of countries;

(c) that, if such transmissions become general without international coordination, serious problems of interference to existing broadcasting services could arise;

(d) that, by the adoption of suitable techniques on an international scale, such interference problems could be avoided and spectrum occupancy reduced;

(e) that it is desirable to achieve international standardization of transmission parameters, so as to make possible the standardization of some parts of receivers for stereophonic broadcasting;

UNANIMOUSLY DECIDES that the following question should be studied:

1. by what methods can satisfactory stereophonic sound be broadcast to ensure maximum economy in frequency usage;

2. what systems can ensure compatibility together with no significant loss of coverage or increase in mutual interference with existing services;

3. what parameters should be standardized?

Note. — " Compatible " implies that, when a stereophonic programme is being broadcast, an ordinary receiver may continue to receive a satisfactory balanced, non-stereophonic programme.

STUDY PROGRAMME 15A/10

STEREOPHONIC BROADCASTING

Standards for compatible systems in sound and television broadcasting

The C.C.I.R. (1959 - 1966)

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the study of systems for compatible stereophonic broadcasting, indicating:

1.1 the general principles of each system;

1.2 the detailed specification of each system;

1.3 the overall theoretical evaluation of the performance of each system;

2. the study of systems with particular regard to their feasibility and applicability to existing broadcast transmitters;

3. the study of systems with regard to:

3.1 performance of existing non-stereophonic receivers when tuned to the stereophonic transmission;

3.2 performance of stereophonic receivers when tuned to the stereophonic signal;

3.3 performance of stereophonic receivers when tuned to non-stereophonic signals;

3.4 possibility of adapting existing non-stereophonic receivers for stereophonic reception;

4. the study of systems with particular regard to:

4.1 coverage;

4.2 interference effects;

4.3 bandwidth involved and other matters concerned with channel utilization;

5. the carrying out of field tests of those systems that appear most satisfactory.

STUDY PROGRAMME 15B/10

TOLERANCES FOR THE AUDIO-FREQUENCY PARAMETERS OF THE STEREOPHONIC TRANSMISSION CHAIN

The C.C.I.R., (1966)

CONSIDERING

(a) that the values given in the Tables of Report 293-2, although comparable on the whole, have not yet led to any general agreement;

(b) that the subjectively determined transmission tolerances, when monitored by a high-grade receiver, are not sufficient for ascertaining the conditions which must be ensured in the different parts of the transmission chain with regard to international exchange of programmes;

(c) that without such specifications, both the IEC and the C.C.I.R. are unable to establish further recommendations, especially for stereophonic recording;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of those sections of the stereophonic transmission chain—from the microphone output to the loudspeaker input—for which it is useful to specify tolerances for the parameters enumerated in the Tables in Report 293-2;

2. the tolerances that should be specified for these parameters under transmitter monitoring conditions;

3. taking into account their subjective nature, whether these tolerances should be subdivided into:

— values to be aimed at;

— values at present valid and attainable.

STUDY PROGRAMME 15C/10

COMPATIBILITY OF A MONOPHONIC SIGNAL OBTAINED FROM A STEREOPHONIC SOURCE

The C.C.I.R., (1970)

CONSIDERING

(a) that the compatibility of stereophonic programmes is determined, among other considerations, by the difference in phase and transmission time between the two channels of a stereophonic system;

(b) that the difference in phase between the two stereophonic channels can be cumulative over successive components in the system;

(c) that the differences in phase depend on the source of the programme and the programme link;

(d) that the tolerance limits for phase differences between channels as shown in Fig. 3 of Report 293-2 for stereophonic reproduction may not be adequate for listening to the compatible monophonic signal;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the limits of perceptibility of the phase differences between channels for compatibility in the frequency range 40 Hz to 15 kHz;

2. determination of the feasibility of controlling the phase differences between channels of a system (amplifying, recording, reproducing, broadcasting or receiving);

3. determination of the permissible phase-shift distribution between the various parts of the system;

4. determination of the electrical and mechanical characteristics of the equipment to satisfy the phase-shift distribution limits;

5. definition of applicable methods of measurement.

QUESTION 16/10

TECHNIQUES FOR CHECKING THE ESSENTIAL CHARACTERISTICS OF FREQUENCY-MODULATION STEREOPHONIC BROADCASTING

The C.C.I.R., (1965)

CONSIDERING

(a) that incorrect modulation in frequency-modulation stereophonic broadcasting can result in objectionable crosstalk between channels *A* and *B*, and possibly between the stereophonic and supplementary communication multiplex channels. It can also produce objectionable distortion in stereophonic or in compatible monophonic reception;

(b) that ensuring correct stereophonic modulation involves the measurement of quantities which are not encountered in monophonic broadcasting (e.g. the relative polarity of the *A* and *B* audio-frequency signals and, in the case of the pilot-tone system, the phase of the pilot-tone);

UNANIMOUSLY DECIDES that the following question should be studied:

what techniques can be used to ensure that the transmitted signal conforms to the system specification?

STUDY PROGRAMME 16A/10

CHECKING STEREOPHONIC MODULATION CHARACTERISTICS

Parameters and methods

The C.C.I.R., (1966)

CONSIDERING

(a) that the problem of checking stereophonic transmissions requires thorough study, especially with regard to the parameters to be checked at the transmitter output;

(b) that it is also important to extend these studies to include studio and transmitter links;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. Checking of stereophonic transmissions

1.1 the parameters that it is essential or desirable to check during transmission, to ensure that the transmitter output signal conforms to the specifications for the stereophonic system used;

1.2 the parameters it would be useful to adjust during routine maintenance;

1.3 the most appropriate methods for these checks.

2. Checking of stereophonic links

2.1 the parameters it is essential or desirable to check during operation, to preserve stereophonic quality;

2.2 the parameters it would be useful to check during routine link maintenance;

2.3 the most appropriate methods for these checks.

QUESTION 17-1/10

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND PROGRAMMES IN FREQUENCY-MODULATION BROADCASTING

The C.C.I.R., (1966 - 1970)

CONSIDERING

(a) that, for certain applications, in frequency-modulation broadcasting, it might be desirable to transmit two or more sound programmes simultaneously;

(b) that such transmissions might be particularly useful in areas where several languages are spoken;

(c) that two or more programmes might be transmitted with a specially designed system;

(d) that use of existing receivers (adapted or modified) for reception of the supplementary programmes is not to be considered a primary requirement;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what systems can be used with a single transmitter for the transmission of one or more supplementary sub-carrier programmes in frequency-modulation broadcasting;

2. what types of receiver should be used, to allow the listener to select each programme;

3. what specifications should be recommended for these purposes?

STUDY PROGRAMME 17-1A/10

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND PROGRAMMES IN FREQUENCY-MODULATION BROADCASTING

Choice of parameters

The C.C.I.R., (1970)

CONSIDERING

that there are several methods of transmitting simultaneously two or more sound programmes using a single frequency-modulation carrier;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. Technical parameters to be standardized

1.1 the frequency of each sub-carrier;

1.2 the type of modulation of the sub-carriers;

1.3 the degree of modulation of the main carrier by each sub-channel signal;

1.4 the degree of modulation of each sub-carrier if frequency modulation is chosen;

1.5 the maximum audio modulating frequency;

1.6 the pre-emphasis characteristics of supplementary channels;

1.7 the time constants and input/output characteristic of any compressor/expander used in the system;

1.8 the dynamic range;

1.9 any other parameters which need to be considered;

2. Influence of these characteristics upon

2.1 the intermodulation between the different channels;

2.2 the signal-to-noise ratio of each channel;

2.3 the frequency response of each channel;

2.4 the harmonic distortion in each channel;

2.5 the radio-frequency protection ratios;

2.6 stereophonic broadcasting.

QUESTION 18-1/10

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND CHANNELS IN TELEVISION

The C.C.I.R., (1959 – 1963 – 1970)

CONSIDERING

(a) that it is often desirable, for the purpose of international television programme exchange, to transmit two or more sound channels simultaneously;

(b) that such a transmission may also be useful in areas where several languages are spoken;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what systems can be used, preferably with a single transmitter, for the transmission of two or more sound channels in television. These systems should not involve any significant increase in bandwidth of the television channel. Moreover, existing types of receiver should be able to receive, without modification, one of the sound channels while maintaining picture and sound quality;

2. what modifications would need to be made to existing types of receiver, to allow the viewer to select individually any of the transmitted sound channels;

3. to what extent could these systems be used for stereophonic sound transmissions in television;

4. what change in service area (determined by either random noise, impulsive noise or interference) would arise from the introduction of such systems, as compared with the service areas for existing single sound channel transmission;

5. what crosstalk attenuation between the transmitted sound channels would be obtained with such systems?

STUDY PROGRAMME 18-1A/10

SIMULTANEOUS TRANSMISSION OF TWO SOUND CHANNELS IN TELEVISION

Objective method of measurement of crosstalk

The C.C.I.R., (1966)

CONSIDERING

that the spectral distribution of crosstalk depends upon the system in use;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the best objective method for measuring crosstalk, giving results comparable with subjective assessments.

STUDY PROGRAMME 18-1B/10

SIMULTANEOUS TRANSMISSION OF TWO OR MORE SOUND CHANNELS IN TELEVISION

The C.C.I.R., (1970)

CONSIDERING

(a) that for the transmission of two sound channels in television on the normal sound carrier, a sub-carrier FM-FM system appears to meet the requirements more satisfactorily than other sub-carrier systems;

(b) that a sub-carrier frequency which is a multiple of the line frequency appears to be the best choice;

(c) that the use of compressors and associated expanders improves the signal/noise ratio;

(d) that in many cases a second carrier can be added to the sound transmitter for the transmission of a second sound channel, without causing adjacent channel interference;

UNANIMOUSLY DECIDES that the following studies should be carried out:

characteristics which should be standardized for:

— the FM-FM sub-carrier system,
— the supplementary sound-carrier system,
— a combination of both the above systems for the transmission of more than two sound channels.

QUESTION 19/10

FREQUENCY-MODULATION BROADCASTING IN BAND 8 (VHF)

Polarization of emissions

The C.C.I.R., (1965 – 1966)

CONSIDERING

that emissions from frequency-modulation broadcasting stations are usually transmitted with horizontal polarization;

UNANIMOUSLY DECIDES that the following question should be studied:

1. are there advantages, both in improving service and minimizing interference, in using for monophonic and stereophonic sound broadcasting in band 8 (VHF):

1.1 vertical polarization only;

1.2 emissions from the same location on the same frequency with both horizontal and vertical polarization;

2. what types of antennae can be used for transmission and reception?

QUESTION 20-1/10 *

BROADCASTING-SATELLITE SERVICE

Sound broadcasting

The C.C.I.R., (1965 – 1966 – 1970)

CONSIDERING

(a) Recommendation No. Spa 5 of the Extraordinary Administrative Radio Conference, Geneva, 1963;

(b) that sound broadcasting from satellites may soon become possible because of technical progress;

(c) that the technical consequences of sound broadcasting from satellites must be taken into account, including the possibility of sharing frequency bands between sound broadcasting satellites and the terrestrial broadcasting service as well as other terrestrial services;

(d) that the use of sound broadcasting satellites could cause difficulty in sharing frequency bands between broadcasting satellites and other space services, and will also affect the utilization of the geostationary orbit;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the optimum transmission characteristics for single and multiple sound broadcasting from satellites taking into account both transmission and reception equipment;

2. what are the frequency bands which are technically suitable for sound broadcasting from satellites;

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* Contributions to the study of this Question should be brought to the attention of participants in the work of Study Groups 4 and 11 and of Study Group 9 for contributions on §§ 4 and 5.

3. what are the possibilities for sharing frequency bands between sound broadcasting satellites and the terrestrial broadcasting service;

4. what are the possibilities for frequency sharing between sound broadcasting satellites and terrestrial services other than broadcasting, particularly in bands 9 and 10;

5. what are the field-strength values necessary to provide satisfactory reception of a broadcasting satellite and protect terrestrial services if frequency sharing is envisaged;

6. what are the possibilities of sharing frequency bands between sound broadcasting satellites taking into account, if necessary, the efficient utilization of the geostationary orbit;

7. what are the possibilities of sharing frequency bands between sound broadcasting satellites and those of television or space services other than broadcasting taking into account, if necessary, the efficient utilization of the geostationary satellite orbit;

8. what other aspects of planning, designing and operating systems using broadcasting satellites influence the choice of the principal characteristics of such systems, taking into account technological developments?

STUDY PROGRAMME 20-1A/10

BROADCASTING-SATELLITE SERVICE FOR COMMUNITY RECEPTION

Sound broadcasting

The C.C.I.R., (1970)

CONSIDERING

(a) the possibility of community reception as defined in Report 293-2;

(b) that new and developing countries are especially interested in the study of community reception;

(c) that operating conditions and reception quality for community reception of signals from broadcasting satellites are expected to be appreciably different from the conditions and reception quality for individual reception;

(d) that this difference in operating conditions and reception quality may well enable a satisfactory sound broadcasting satellite service to be established at an early date, and at a reasonable cost;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the optimum characteristics of a sound broadcasting satellite for community reception, to provide economical coverage of areas of the earth which are not generally served by sound broadcasting transmitters;

2. the frequency bands which would be technically appropriate;

3. the possibilities of frequency sharing with other broadcasting services;

4. the system of transmission to be used to assure the optimum service at the lowest cost.

STUDY PROGRAMME 20-1B/10

POSSIBLE SOUND BROADCASTING SATELLITE SYSTEMS AND THEIR RELATIVE ACCEPTABILITY

The C.C.I.R., (1970)

CONSIDERING

(a) that it is technically possible at present to establish a terrestrial sound broadcasting service with distribution of programmes by earth stations participating in the communication-satellite service;

(b) that studies of the technical characteristics of a system of direct sound broadcasting by satellites are now being undertaken;

(c) that, to supplement these technical characteristics, the cost of such systems (covering both the capital cost and the running cost) should be taken into account;

(d) that these factors influence the choice of systems;

(e) that comparative cost is not the absolutely deciding factor but an extra consideration to be borne in mind;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. comparison of the different sound broadcasting satellite systems, for either individual or community reception, taking the technical aspects and the capital and running costs into account;

2. evaluation of the feasibility and possible uses of each system in the light of the technical and economic factors involved.

Note. — These studies will be carried out taking into account the more detailed economic studies made by the Technical Cooperation Department of the I.T.U. and in conjunction with that Department.

QUESTION 25/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

The C.C.I.R., (1968 – 1970)

CONSIDERING

(a) that any sound broadcasting system should specify the essential emission and reception characteristics taking into account the effects of propagation;

(b) that the system, or systems, chosen should permit efficient use of the frequency bands available, whilst maintaining reasonable receiver costs;

(c) that apart from the double-sideband amplitude-modulation system, other systems may be used;

(d) that sky-wave and/or ground-wave reception may be required;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what sound broadcasting systems should be standardized;

STUDY PROGRAMME 20-1C/10*

BROADCASTING-SATELLITE SERVICE IN THE 12 GHz BAND

(1972)

The C.C.I.R.,

CONSIDERING

(a) that the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971) allocated a band of frequencies at about 12 GHz on a primary basis for the broadcasting-satellite service;

(b) that this band is also allocated on a primary basis to other services, the requirements of which must be respected;

(c) that there may, in due course, be a very substantial demand for frequency assignments for the broadcasting-satellite service in this band;

(d) that it is important to make the best possible use of the geostationary-satellite orbit and of the frequency band allocated to the broadcasting-satellite service;

(e) that whenever possible the " service area " should be the minimum necessary to provide the required coverage;

(f) that it is necessary to prepare plans on a world-wide or regional basis for the establishment of broadcasting-satellite services (see Resolution No. Spa2 – 2);

DECIDES that the following studies should be carried out:

determination of the essential planning parameters to be recommended for the preparation of a frequency plan for the broadcasting-satellite service in the 12 GHz band.

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* This Study Programme is identical to Study Programme 5-1G/11.

2. what should be the characteristics of these systems with respect to:
   - the emission (type of modulation, audio-frequency bandwidth and necessary bandwidth of emission, dynamic compression, pre-emphasis, limiting, channel spacing, etc.);
   - reception (principle of demodulation, audio-frequency response, dynamic expansion, de-emphasis, intermediate frequency, etc.);
3. should a system differing from the present system be chosen, what are the consequences resulting from that choice during any transition period on:
   - existing receivers;
   - receivers constructed in conformity with the new system?

STUDY PROGRAMME 25A/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Radio-frequency protection ratios

The C.C.I.R. (1968 - 1970)

UNANIMOUSLY DECIDES that the following studies should be carried out:

the determination of radio-frequency protection ratios under conditions which take account simultaneously of the following items, which may vary independently of each other:

1. **Fading** (see Study Programme 25D/10):

1.1 wanted signal and unwanted signal stable;*

1.2 wanted signal stable, and unwanted signal fluctuating;*

1.3 wanted signal and unwanted signal fluctuating;*

1.4 wanted signal fluctuating and unwanted signal stable;*

2. **Frequency separation** from 0 to 30 kHz between the wanted and unwanted carrier;

3. **Broadcasting programmes**

3.1 wanted and unwanted signals modulated with the same programme;*

3.2 wanted and unwanted signals modulated with different programmes;*

4. **Class of emission** (the characteristics should be stated in each case)

4.1 double-sideband amplitude modulation:

4.1.1 with current-type receivers;

4.1.2 with receivers with characteristics adapted to the defined double-sideband transmission;

4.2 single-sideband or vestigial-sideband, including compatible single-sideband modulation;**

4.2.1 with current-type receivers;

4.2.2 with receivers specially adapted to the system considered;

4.3 any other class of emission;

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* Tests should also be made with several unwanted signals.

** A transmission is said to be " compatible " if it can be received on an existing conventional receiver, without any modification whatsoever to the receiver, and then gives a quality of reception at least as satisfactory as that obtained at present in a double-sideband system.

4.4 coexistence of two systems as follows:

Wanted emission	Unwanted emission
Double-sideband amplitude-modulation	Class of emission as under §§ 4.2 or 4.3
Class of emission as under §§ 4.2 or 4.3	Double-sideband amplitude-modulation

5. frequency band (5 (LF), 6 (MF) or 7 (HF));

6. minimum field strength to be protected;

7. compression of dynamic range;

8. necessary bandwidth.

Note. — Recommendation 413-1 gives the form in which the results should be presented.

STUDY PROGRAMME 25B/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Objective two-signal methods of measurement of radio-frequency protection ratios

The C.C.I.R., (1968 - 1970)

CONSIDERING

(a) that subjective methods for determining the necessary radio-frequency protection ratios are complicated and difficult to carry out because of the many parameters involved;

(b) that objective methods for determining the selectivity of receivers based on single-signal techniques cannot be used to determine these radio-frequency protection ratios;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the objective two-signal methods of measurement that can be used to measure radio-frequency protection ratios for various sound-broadcasting systems including double-sideband, vestigial-sideband, single-sideband and others.

STUDY PROGRAMME 25C/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Minimum field strength to be protected

The C.C.I.R. (1968 – 1970)

UNANIMOUSLY DECIDES that the following studies should be carried out:

the minimum field strength to be protected for broadcasting in bands 5 (LF), 6 (MF) and 7 (HF), taking account of:

— the characteristics of the system;

— whether ground-wave or sky-wave reception is envisaged;

— atmospheric noise;

— industrial noise.

STUDY PROGRAMME 25D/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Reception of the sky-wave signal

The C.C.I.R. (1968 – 1970)

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the nature of the distortion due to the effects of the ionosphere at distances beyond the ground-wave service area;
2. the degradation of the subjective quality of the sky-wave signal when received beyond the limit of the ground-wave service area, according to the system envisaged and as a function of distance and other possible factors, such as the geographical location of the transmitter, the frequency, the season of the year and the characteristics of the transmitting antenna
3. the degree of distortion for a given percentage of time that would, after demodulation at the receiver, provide satisfactory sky-wave reception;
4. the reduction in distortion due to the effects of the ionosphere that can be secured by improvements in methods of detection, e.g. replacing the envelope detectors by other detection devices.

Note. — See also Question 11-1/10.

STUDY PROGRAMME 25E/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF) AND 6 (MF)

Limitation of radiated power taking account of ionospheric cross-modulation

The C.C.I.R., (1968 – 1970)

CONSIDERING

that ionospheric cross-modulation can result from high-power radiation;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the maximum permissible radiated power in bands 5 (LF) and 6 (MF), as a function of the angle of elevation, to ensure that the effects of ionospheric cross-modulation are not disturbing.

Note. — See Questions 11-1/10 and 13/10.

STUDY PROGRAMME 25F/10

SOUND BROADCASTING SYSTEMS IN BANDS 5 (LF), 6 (MF) AND 7 (HF)

Broadcasting coverage

The C.C.I.R. (1968 - 1970)

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the dependence of ground-wave and sky-wave sound broadcasting coverage on:
   - — the characteristics of the system;
   - — the radio-frequency protection ratios;
   - — the channel spacing;
   - — the minimum field strength to be protected;
   - — the radiated power;
   - — the geographical distribution of the transmitters;
   - — the use of directional transmitting antennae;
   - — the use of groups of synchronized transmitters,

   for bands 5 (LF), 6 (MF) and 7 (HF);

2. methods for calculating the minimum number of channels required for the coverage for broadcasting in bands 5 (LF) and 6 (MF), for each of the systems envisaged, taking into account the items listed under § 1 and the possibility of using computers.

Note 1. — The results of Study Programmes 25A/10, 25C/10, 25D/10 and 25E/10 and the propagation data worked out by Study Groups 5 and 6 should be taken into account.

Note 2. — Attention is drawn to Resolution No. 5 of the African LF/MF Broadcasting Conference, Geneva, 1966, and to Resolution No. 614 of the Administrative Council of the I.T.U., Geneva, 1967, with particular respect to the problem of channel spacing.

QUESTION 26/10

TRANSMISSION OF ADDITIONAL PROGRAMMES IN FREQUENCY-MODULATION SOUND BROADCASTING IN BAND 8 (VHF)

The C.C.I.R., (1970)

CONSIDERING

that a large number of countries need to transmit additional programmes for frequency-modulation sound broadcasting in band 8 (VHF);

UNANIMOUSLY DECIDES that the following question should be studied:

1. which of the following systems is to be preferred from the viewpoint of economy of the radio-frequency spectrum if, in each system, the same service areas (limited by noise and/or interference) and the same audio-frequency qualities are provided by the corresponding main and supplementary channels:

1.1 transmission of the additional programmes by systems using frequency-division multiplex;

1.2 transmission of the additional programmes by separate monophonic transmitters of an adequate power;

1.3 any other systems;

2. to what extent it is possible to increase the service area of the additional programme transmissions by using either a compressed signal at the input to the transmitter only or a complete compander system, without increasing the level of interference to reception of other emissions and without decreasing the quality of reception;

3. to what extent are receivers, generally available, suitable for the reception of the additional programmes with or without a change in the quality of reception?

QUESTION 27/10 *

INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING

The C.C.I.R., (1948 – 1951 – 1953 – 1963 – 1970)

CONSIDERING

Recommendation No. 3 of the Administrative Radio Conference, Geneva, 1959, and the studies pursued at the Plenary Assemblies of the C.C.I.R.

UNANIMOUSLY DECIDES that the following question should be studied:

what is the minimum permissible protection ratio for broadcasting signals, when measured at the output of a receiver fitted with a filter having an audio-frequency cut-off of 5 kHz and to what minimum value of the wanted field should this ratio be maintained?

* This Question replaces Question 1/XII of former Study Group XII.

STUDY PROGRAMME 27A/10 *

SHORT-DISTANCE BROADCASTING IN BAND 7 (HF) IN THE TROPICAL ZONE

The C.C.I.R., (1951 – 1956 – 1963 – 1970)

CONSIDERING

(a) that few data exist on the determination of the power required for a given grade of broadcasting service in the Tropical Zone (defined in the Annex);

(b) that it would be helpful in the planning of new broadcasting services in the Tropical Zone to have more reliable data;

(c) that more reliable data would be helpful in the organization of services in the bands shared with broadcasting in the Tropical Zone (see No. 425 of the Radio Regulations);

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the experimental determination of the signal-to-noise ratio and the signal-to-interference ratio that should be adopted as representative of an acceptable broadcasting service in the Tropical Zone. The observations should be made with antennae and receivers that are representative of those normally used for broadcasting reception in the Tropical Zone. The reports on this study should indicate, as fully as possible, the conditions of measurement, the characteristics of the equipment and the methods used, so that the results may be correlated with those of other observers. In particular, the bandwidth of the receiver employed should be given;

2. a practical examination of whether the provisional power limits in Recommendation 215 are satisfactory or whether they should be changed to give an acceptable broadcasting service in the Tropical Zone. The reports on this study should include all the relevant factors concerned and, in particular, information on the following points:

   — the area and the hour, day, month and year for which observations are made;

   — the distance from the transmitter to the point of observation;

   — the carrier power of the transmitter and its depth of modulation;

   — the details of the transmitting and receiving antennae;

   — the characteristics of the receiver used.

   Information on the signal-to-noise ratio and the signal-to-interference ratio (if possible in a statistical form) would also be helpful (see also § 1 above). Any conditions peculiar to the area concerned and which have an important bearing on the transmitted power required, should also be stated;

3. the study of natural noise in the Tropical Zone, with particular reference to broadcasting conditions. The aim should be to provide noise data (in a statistical form if possible), which could be used in problems concerning the field strength or radiated power required to produce a given grade of broadcasting service. The method of measurement used should be clearly defined, particularly as concerns the bandwidth of the measuring equipment. Particular attention should be paid to those frequency bands allocated to broadcasting below 16 MHz, which could be used for broadcasting in the Tropical Zone and to the normal broadcasting listening hours (approximately 0600 to 2400 h local time);

* This Study Programme replaces Study Programme 1A/XII of former Study Group XII.

4. study of the field strength produced by broadcasting transmitters in the Tropical Zone. Reports should, if possible, be evaluated on a statistical basis, and should give, in particular, the following information:

— method of measurement employed;

— methods of analysis;

— location of the transmitter;

— distance from the transmitter at which measurements are made;

— radiated carrier power;

— polar diagram of the transmitting antenna (or equivalent data);

— period during which measurements are made;

— radio-frequency used.

It might be convenient to carry out this study in conjunction with those outlined in §§ 1 and 2 above. If it is possible to make measurements of the field strength produced outside the service area of the tropical broadcasting station, the resulting information would also be helpful in determining the degree of interference produced to other services which share frequency bands with broadcasting in the Tropical Zone.

ANNEX

A short-distance broadcasting service in band 7 (HF) is an indirect-ray service in which the incident ray meets the reflecting layer at a considerable angle to the horizontal and there is no appreciable skip distance between the transmitter and the service area. The outer limit of a short-distance service is considered as being 800 km.

(Taken from Question 27, which was terminated by Recommendation 84, subsequently replaced by Recommendation 215).

STUDY PROGRAMME 27B/10 *

INTERFERENCE IN THE FREQUENCY BANDS USED FOR BROADCASTING IN THE TROPICAL ZONE

The C.C.I.R., (1956 – 1970)

CONSIDERING

(a) that the limited data available on the measured field strength of broadcasting emissions in the Tropical Zone operating in the bands 2300 kHz to 5060 kHz, and in the high-frequency broadcasting bands above 5060 kHz normally used for broadcasting in the Tropical Zone, are insufficient to arrive at the minimum signal to be protected, as required in Question 27/10;

(b) that the method of propagation affecting the field-strength values is not clearly known;

* This Study Programme replaces Study Programme 1B/XII of former Study Group XII and is identical with that text.

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. extensive field-strength data should be collected on broadcast emissions in the Tropical Zone in the bands 2300 kHz to 5060 kHz and in the high-frequency broadcasting bands above 5060 kHz:
   - about 50 km;
   - 200 to 300 km;
   - 800 to 1200 km;

and, if possible, at appreciably greater distances from the transmitters;

2. measurements as in § 1 shall be carried out simultaneously with experimental observation of signal-to-noise ratios.

STUDY PROGRAMME 27C/10 *

INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING

(Recommendation 216)

The C.C.I.R., (1953 – 1956 – 1959 – 1970)

CONSIDERING

(a) that Recommendation 216 does not provide a final answer to § 6, Question 27/10 (formerly Question 1/XII) and recommends a further study, to determine finally a value for the minimum permissible protection ratio for broadcasting services operating in the Tropical Zone in the shared bands;

(b) that sufficient new data are not yet available to answer Question 27/10, § 6;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. experimental determination of the minimum protection ratio to be provided for a broadcasting station, operating in the shared bands in the Tropical Zone, against interference from telegraphy (A1 and A2) and telephony (A3) emissions when:
   - the interference is caused by one of these three types of emission;
   - the interference is caused by two or more types of emission at the same time;

1.1 this study should be carried out taking into account transmitter frequency variations (up to and including those equal to the sum of the permissible frequency tolerances) of the broadcasting service in the Tropical Zone and other services sharing the bands as laid down in the current Radio Regulations;

1.2 measurements should be carried out at the output of a receiver fitted with a simple filter having an audio-frequency cut-off of 5 kHz (the characteristics of the filter employed should be given);

1.3 measurements should also be carried out for cut-off frequencies of 6, 7, 8 and 9 kHz;

1.4 measurements should be carried out for carrier frequencies separated by 0, 1, 2, ... 10 kHz;

1.5 the results should be expressed in terms of percentage of listener satisfaction, as well as of percentage of time during which the satisfaction is achieved;

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* This Study Programme replaces Study Programme 1C/XII of former Study Group XII and is identical with that text.

2. experimental determination of the minimum field strength to which a protection ratio, as defined in § 1, should relate (taking into account the nature, intensity and distribution of noise levels in different parts of the Tropical Zone).

QUESTION 28/10 *

BEST METHOD FOR CALCULATING THE FIELD STRENGTH PRODUCED BY A BROADCASTING TRANSMITTER IN THE TROPICAL ZONE

(Report 305-2)

The C.C.I.R., (1951 – 1956 – 1963 – 1970)

CONSIDERING

(a) the importance of being able to calculate the power required to produce a given field strength under given conditions for broadcasting in the Tropical Zone (defined in the Annex to Study Programme 27A/10);

(b) that reliable methods of calculation would assist the planning of new broadcasting services in the Tropical Zone and the allotment of frequencies to services in the Tropical Zone;

(c) that few basic data exist concerning ionospheric absorption for the Tropical Zone, and its dependence upon the time of day, the season and the sunspot cycle;

(d) that the relation between ionospheric absorption at oblique incidence and that at vertical incidence is not yet fully understood;

(e) that there is no internationally agreed method of examining the nature of the multiple reflections and of calculating the resultant field strength occurring at the intermediate distances involved in broadcasting in the Tropical Zone;

DECIDES that the following question should be studied:

1. what is the best method that may be used for calculating the field strength produced at the surface of the Earth by the indirect ray, at various distances between 0 and 800 km and between 800 and about 4000 km, by a transmitter situated in the Tropical Zone (as defined in Appendix 24 to the Radio Regulations), radiating a power of 1 kW from a half-wavelength dipole situated $\frac{1}{4}$ and $\frac{7}{16}$ of a wavelength above ground respectively, and operating in any of the frequency bands used for broadcasting in the Tropical Zone (i.e. the " shared bands " listed in Art. 7, No. 425, and the general broadcasting bands below 15 450 kHz, listed in the Table of Frequency Allocations, Art. 5 of the Radio Regulations), at any season, and for sunspot numbers of about 5, 60 and 125, respectively, during normal listening hours (approximately 0600 to 2400 h local time);

2. what is the probable error in the proposed method of calculation;

3. what basic data should be used in the proposed method of calculation;

4. what is the probable statistical distribution of the fading of the signal?

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* This Question replaces Question 2/XII of former Study Group XII and is identical with that text.

QUESTION 29/10 *

DESIGN OF TRANSMITTING ANTENNAE FOR BROADCASTING IN THE TROPICAL ZONE

(Report 301-2)

The C.C.I.R., (1951 – 1953 – 1956 – 1970)

CONSIDERING

(a) that the average radius of a broadcasting service area in the Tropical Zone is about 800 km;

(b) the necessity for further study of the design of transmitting antennae for broadcasting in the Tropical Zone, for the purpose of concentrating the energy transmitted by reflection from the ionosphere as much as possible into the desired service area;

(c) that the use of efficient antennae for transmission would permit the use of transmitters of lower power;

(d) the importance of reducing interference to a minimum between services which share frequency bands, as provided by Nos. 425 and 426 of the Radio Regulations;

(e) the provisions of No. 695 of the Radio Regulations;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what factors determine the best position of the transmitting antennae, with respect to the area to be served, to concentrate the energy received by reflection from the ionosphere within the desired service area and to reduce to a minimum the amount of energy received outside the broadcast service area;

2. what practical improvements, confirmed by measurement, can be made in the design of transmitting antennae for broadcasting in the Tropical Zone, to concentrate the energy received by reflection from the ionosphere within the desired service area and to reduce to a minimum the energy received outside the broadcast service area; in particular, what steps can be taken to reduce low-angle radiation to a minimum?

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* This Question replaces Question 3/XII of former Study Group XII and is identical with that text.

QUESTION 30/10 *

FADING ALLOWANCES FOR BROADCASTING IN THE TROPICAL ZONE

(Report 301-2)

The C.C.I.R., (1956 - 1970)

CONSIDERING

(a) that Recommendation 340 and Study Programme 1A-1/3 only concern the allowances for protection of fading signals for broadcasting in general;

(b) that broadcasting in the Tropical Zone has special characteristics which differ from those of high-frequency broadcasting for long distances;

(c) that the nature, type and intensity of fading of broadcasting emissions under tropical conditions of propagation are peculiar and require further study;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the different types and characteristics of fading encountered in the Tropical Zone;
2. what is the annoyance value to reception from the point of view of listener satisfaction;
3. what allowances should be provided for planning broadcasting services in the Tropical Zone?

QUESTION 31/10 **

DETERMINATION OF THE EFFECTS OF ATMOSPHERIC NOISE ON THE GRADE OF RECEPTION IN THE TROPICAL ZONE

The C.C.I.R., (1951 – 1956 – 1963 – 1970)

CONSIDERING

that the determination of the transmitter power required depends in part upon the value of the signal-to-atmospheric noise ratio, regarded as being the minimum for an acceptable broadcasting service in the Tropical Zone;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what characteristics of atmospheric noise are important in determining the response of a typical broadcast receiver and to what extent do they affect the grade of reception;
2. what average value of signal-to-atmospheric noise ratio is required to ensure satisfactory reception for at least 90% of the total time?

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* This Question replaces Question 4/XII of former Study Group XII and is identical with that text.

** This Question replaces Question 5/XII of former Study Group XII and is identical with that text.

QUESTION 32/10

BROADCASTING IN BAND 8 (VHF) IN THE TROPICAL ZONE

The C.C.I.R., (1970)

CONSIDERING

(a) that broadcasting in band 8 of the radio-frequency spectrum is providing a high-quality service in many parts of the world;

(b) that the rate of failure of transmission systems in band 8 is extremely low;

(c) that domestic receivers with adequate sensitivity are readily available for operation in band 8;

(d) that systems operating in band 8 are most economical in areas with a high density of population;

(e) that there may be special applications for broadcasting in band 8 in the Tropical Zone;

UNANIMOUSLY DECIDES that the following question should be studied:

what are the advantages and disadvantages of using band 8 for broadcasting applications in the Tropical Zone?

STUDY PROGRAMME 33A/10 *

USE OF SINGLE-SIDEBAND RECEPTION FOR MINIMIZING FADING EFFECTS FOR RE-BROADCAST APPLICATIONS WITHIN THE TROPICAL ZONE

The C.C.I.R., (1968 - 1970)

CONSIDERING

(a) that the quality of broadcasting in band 7 (HF) within the Tropical Zone suffers greatly from the ill-effects of selective fading and peculiar types of " surge " ** and " flutter " fading;

(b) that development of techniques to minimize the ill-effects of these types of fading will improve the quality of re-broadcast services within the Tropical Zone;

(c) that results of these studies will also be of interest to Study Groups 1, 3 and 6;

* This Study Programme, formerly Study Programme 7A/XII, does not arise from any Question under study.

** As compared with " flutter fading ", " surge fading " is a slower but deeper form of fading accompanied by severe distortion. This peculiar type of fading gives the impression of the signal being received in powerful " surges ".

DECIDES that the following studies should be carried out:

1. the extent to which the use of single-sideband reception can improve the quality of broadcasting in band 7 (HF) for re-broadcast applications within the Tropical Zone by way of:
   — reduction in selective fading,
   — reduction in " surge " and " flutter " fading;

2. determination of the preferred characteristics of such a system of single-sideband reception for re-broadcast applications.

QUESTION 34/10 *

FEASIBILITY OF DIRECT SOUND AND TELEVISION BROADCASTING FROM SATELLITES

The C.C.I.R., (1966 - 1970)

CONSIDERING

(a) that there are many parts of the world with little or no broadcasting service;

(b) that there is considerable interest in the possibility of broadcasting from satellites;

(c) that, in view of the extensive use of existing broadcasting bands below 1 GHz in some regions, there is particular interest in the feasibility of using frequencies above 1 GHz;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the satellite orbits most satisfactory for direct broadcasting to the general public from satellites;

2. what accuracy of positioning or station keeping can be achieved;

3. what maximum primary power is likely to be available to operate a transmitter in a satellite, and what other factors associated with the space environment operate to limit the power that could be developed in the transmitter at the various frequencies that might be used, up to 12·7 GHz, or possibly higher frequencies;

4. what gain, directivity and stability of orientation are attainable for satellite transmitting antennae at various frequencies;

5. what is the probable working life of a satellite, bearing in mind that failure in accurate positioning or antenna orientation may end the useful life?

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* This Question, which replaces Question 12/IV and which is identical with Question 23/11, should be studied in connection with Questions 20-1/10 and 5-1/11. Contributions to the study of this Question should be brought to the attention of participants in the work of Study Group 11.

RESOLUTION 38

POSSIBLE BROADCASTING SATELLITE SYSTEMS AND THEIR RELATIVE ACCEPTABILITY

(Study Programmes 20B/10 and 5C/11)

The C.C.I.R., (1970)

CONSIDERING

(a) that studies of the technical characteristics of broadcasting satellite systems are now being undertaken;

(b) that, to supplement these technical characteristics, the comparative costs of such systems (covering both capital investment in and the operation of the major sub-systems) should be taken into account;

STUDY PROGRAMME 36A/10*

CHARACTERISTICS OF SOUND BROADCASTING RECEIVERS AND RECEIVING ANTENNAE

(1972)

The C.C.I.R.

DECIDES that the following studies should be carried out:

1. determination of the main characteristics of receiving installations, receivers and antennae which may be useful for frequency planning work, particularly by Administrative Conferences, the I.F.R.B. and other organizations concerned;

2. feasibility of assembling data on the technical characteristics of receivers and antennae and their installation, in a single section of the C.C.I.R. books;

3. incorporation of the data of Recommendations 415 and 416 on low-cost receivers and the results of Study Programme 20-1B/10 concerning satellite broadcast receiving installations into the results of the present study.

Note 1. — In carrying out these studies, account should be taken of the relevant IEC publications. The IEC should be informed of the C.C.I.R.'s requirements and invited to comment (See Opinion 32).

Note 2. — The above-mentioned studies relate to all types of sound broadcasting receivers: AM and FM receivers, monophonic and stereophonic receivers, AM or FM multiplex receivers.

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* Since this Study Programme depends upon three Questions, namely, Questions 15/10, 17-1/10 and 25/10, new drafts having been proposed in respect of the last two, the Director, C.C.I.R., considers that at the moment it is preferable to regard this Study Programme as not deriving from a Question.

(c) that these technical and economic factors may influence the choice of systems;

(d) that these considerations are of particular importance and urgency for new and developing nations;

(e) that studies undertaken by the C.C.I.R. on possible broadcasting satellite systems and their relative acceptability should provide useful information to the Technical Cooperation Department of the I.T.U.;

UNANIMOUSLY DECIDES

1. that an Interim Working Party be established to carry out the following studies:

1.1 comparison of different broadcasting satellite systems or sub-systems intended for either individual or community reception, taking the technical aspects and relative capital and running costs into account;

1.2 evaluation of the feasibility and possible uses of each system in the light of the technical and economic factors involved, taking into consideration especially the operational requirements of new and developing countries;

2. that the concerned countries are urged to make known to the Chairman of the Interim Working Party their particular requirements at the earliest date possible;

3. that the Interim Working Party should be composed of representatives appointed by the Administrations of Argentina, Australia, Brazil, Canada, Federal Republic of Germany, France, India, Italy, Japan, Malaysia, New Zealand, Pakistan, Sweden, the Union of Soviet Socialist Republics, United Kingdom and United States of America, together with the Chairmen and Vice-Chairmen of the Study Groups concerned;

4. that the Chairman of the Interim Working Party shall be a representative of the Administration of India;

5. that the Interim Working Party shall conduct its work expeditiously and as far as possible by correspondence, and shall only hold such meetings as are deemed absolutely necessary for the execution of its work;

6. that reports of the proceedings of the Interim Working Party will be available to the C.C.I.R. Preparatory Meeting for the World Administrative Radio Conference for Space Telecommunications and a final report to the Director, C.C.I.R., for consideration at the next Plenary Assembly;

7. that this Resolution be brought to the attention of interested organizations in the United Nations.

RESOLUTION 57

DETERMINATION OF THE SUBJECTIVE LOUDNESS OF A BROADCASTING PROGRAMME

The C.C.I.R., (1970)

CONSIDERING

(a) the need to complete quickly the studies required by Question 4/10;

(b) the availability of a provisional magnetic test tape for loudness (prepared by the B.B.C. and distributed by the C.C.I.R. Secretariat) with a comprehensive range of programme material having different subjective loudness characteristics;

UNANIMOUSLY DECIDES

1. that an Interim Working Party should be set up with the following terms of reference:

1.1 to determine the subjective loudness of broadcast programmes (Question 4/10);

1.2 to carry out measurements on the provisional loudness test tape and to amend and comment on this with a view to the provision of a C.C.I.R. reference loudness tape;

2. that the Chairman of this Interim Working Party shall be Mr. P. H. Werner, Direction générale des P.T.T., Speichergasse 6, CH-3000 Berne;

3. that the work shall be carried out insofar as possible by correspondence.

Note. — The following Administrations have already indicated their desire and intention to participate in the work of this Interim Working Party: United States of America, Finland, France, Federal Republic of Germany, India, Nigeria, Republic of South Africa, United Kingdom, Sweden, Switzerland, U.S.S.R.

OPINION 15-2

USE OF THE 26 MHz BROADCASTING BAND

The C.C.I.R., (1953 – 1966 – 1970)

CONSIDERING

(a) that it is important that long-distance broadcasting should use all frequency bands available to it;

(b) that when the smoothed relative sunspot number reaches 70, long-distance broadcast transmissions can be carried out efficiently during daylight hours, over many routes, at frequencies within the 26 MHz broadcasting band;

(c) that these frequencies are seldom used;

(d) that such transmissions on these frequencies, whenever they are possible, are particularly advantageous, because of the very low atmospheric-noise intensity and the low absorption;

(e) that advances in space technology may in the foreseeable future, permit the use of this band for sound broadcasting from satellites;

IS UNANIMOUSLY OF THE OPINION

1. that Administrations should bring to the notice of broadcasting organizations:

1.1 the advantages of the 26 MHz band for long-distance terrestrial broadcasting when ionospheric conditions are favourable;

1.2 that the additional use of this band for sound broadcasting from satellites is under study;

2. that receiver manufacturers be informed of these new possibilities and encouraged to extend the tuning range of their products to permit reception in the 26 MHz band.

OPINION 16-1

ORGANIZATIONS QUALIFIED TO TAKE ACTION ON QUESTIONS OF SOUND AND TELEVISION RECORDING

The C.C.I.R., (1956 – 1970)

CONSIDERING

(a) that differences of opinion may exist as to which of the organizations, the IEC, ISO or C.C.I.R., is in the best position to take action in questions concerning recording;

(b) that unnecessary duplication of work and a multiplicity of standards may result, if the present situation is allowed to continue;

IS UNANIMOUSLY OF THE OPINION

1. that the C.C.I.R. should determine the acceptability of existing standards and should collaborate with other international organizations in formulating new standards, when the existing ones are unsuitable for the international exchange of programmes;

2. that the Director, C.C.I.R. should keep in close touch with the IEC and the ISO, with a view to avoiding unnecessary duplication of work;

3. that to inform the IEC and the ISO of C.C.I.R. studies and decisions, the Director, C.C.I.R. should transmit all relevant documents to these Organizations inviting them to take C.C.I.R. views into account.

SECTION 10/11A: RECORDING OF SOUND AND VIDEO PROGRAMMES

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 265-2 *

STANDARDS FOR THE INTERNATIONAL EXCHANGE OF MONOCHROME AND COLOUR-TELEVISION PROGRAMMES ON FILM

The C.C.I.R. (1956 – 1959 – 1963 – 1966 – 1970)

UNANIMOUSLY RECOMMENDS

that the films used for the international exchange of television programmes should meet the following definitions and standards:

1. Definitions

The types of film referred to in this Recommendation are designated by code words as defined below. The code words should be placed on the identification leader of any film intended for international exchange of programmes and should be used in any related correspondence. The code word consists of a letter and a number (or numbers) in conjunction with two- or three-syllable code words, for example: C 35 COMOPT.

The first letter indicates either monochrome, B, or colour, C, film type. The number, usually 16 or 35, indicates the nominal width of the film in millimetres. The first syllable indicates either a combined sound and picture recording, COM, or separate sound and picture recording, SEP. The last syllable indicates whether the sound recording is magnetic, MAG, or optical, OPT:

— 35-mm colour film with an optical track is C 35 COMOPT;

— 16-mm monochrome film with a magnetic stripe is B 16 COMMAG;

— 16-mm colour film with sound on a separate magnetic film is C 16 SEPMAG.

1.1 If the sound is recorded on a separate film using two tracks, then the syllable DU is inserted between the two syllables of the code word as in the following example:

— a picture film with magnetic sound track is COMMAG;

— a picture film with sound on a separate magnetic film is SEPMAG;

— a picture film with two magnetic sound tracks on a separate film is SEPDUMAG.

1.2 For picture films without sound the designation is MUTE, for example: B 16 MUTE.

1.3 If the picture and the sound films have the same width this is indicated by a single number. If not, then two numbers separated by an oblique stroke are used, the first indicating the width of the picture film, for example:

— 35-mm picture film with magnetic sound track on 16-mm film is 35/16 SEPMAG.

* This Recommendation also replaces Recommendation 264-1.

2. Types of films recommended for international exchange of television programmes

2.1 The international exchange of recorded television programmes on monochrome and colour (types B and C) films should be effected by means of one of the following types:

1 — 35 COMOPT
2 — 16 COMOPT
3 — 16 COMMAG
4 — 16 SEPMAG
5 — 35 MUTE
6 — 16 MUTE
7 — 35 COMMAG
8 — 35 SEPMAG
9 — 35 SEPDUMAG
10 — 16 SEPDUMAG

2.2 Films of types 7 to 10 cannot be exchanged unless there is agreement between the organizations concerned.

Note. — Moreover, although the quality of sound obtainable with 16 COMOPT films is marginal, this type cannot be excluded because of its widespread use. Therefore a reduction of the number of recommended types of sound recordings appears to be impossible at present.

2.3 The fundamental technical parameters of each type listed in § 2.1 should conform to the standards given below.

3. Standards common to all types of film

3.1 Safety film must be used.

3.2 Normally the image on the film should be a photographic positive.

3.3 The picture (frame) frequency should be either 25 or 24 per second. The picture frequency should accompany any reference to programme duration.

3.4 For accurate reproduction of films in television systems some limitations should be placed on the film density range. In colour systems the colour balance of films should also be defined.

All film densities specified below are measured in singly-diffused light. The spectral characteristic of the densitometer should conform with ISO Recommendation R5–1955 for diffuse visual density, Type VIb.

3.4.1 For monochrome film the density corresponding to television white level should be 0·3 to 0·4 but in the case of dyed-base film the total density corresponding to television white level should not exceed 0·5.

Note. — Television white level preferably corresponds to a fully-lit object in the scene, having a reflectance of about 60%. This results in reproduction of fully-lit human faces having reflectances of about 15% to 35% at film densities between 0·2 and 0·5 greater than the density corresponding to television white level.

The maximum density of a film is determined by the scene contrast and the film transfer characteristic. The gradation in areas in the film having densities in excess of 1·6 above that corresponding to white level may be distorted or lost entirely.

3.4.2 For colour film the density corresponding to television white level should be 0·3 to 0·4.

Note. — Television white level preferably corresponds to a fully-lit object in the scene, having a reflectance of about 60%. This results in reproduction of fully-lit human faces having reflectances of about 15% to 35% at film densities between 0·2 and 0·5 greater than the density corresponding to television white level.

The maximum density of a film is determined by the scene contrast and the film transfer characteristic. Shadow areas, in which the reproduction of detail is not essential to the picture, may have densities in the range of 2·0 to 2·5, but it must be recognized that in such areas both image gradation and colour may be distorted or lost entirely.

Both 35-mm and 16-mm colour films should be balanced for projection by an illuminant approximating in spectral distribution to a black body at a colour temperature of 5400°K ± 400°K (Note 1) and, when so illuminated, should provide a pleasing reproduction of neutral grey and skin colours (Note 2).

Note 1. — This value is at present under study for 16-mm film.

Note 2. — This neutral grey balance is very close to a metameric match with a neutral grey in the scene. (The metameric match of two colours is obtained when the visual comparison of these two colours does not permit them to be distinguished by the C.I.E. (International Commission on Illumination) Standard Observer.)

3.5 The dimensions of the films and images recorded thereon should conform to appropriate international standards (see ISO Recommendation R73 for 35-mm film and ISO Recommendation R359 for 16-mm film).

3.6 When films are produced for television by conventional cinematographic methods, allowances should be made for the loss of picture area that occurs both in film-scanning and in domestic receivers. The television-scanned area, the action field and the title area should conform with appropriate international (ISO draft Recommendation No. 1151) or equivalent national standards.

3.7 The normal position for the emulsion side of 35-mm films is internationally recognized as facing the light source when projecting on a reflecting-type screen.

For 16-mm film the same position of the emulsion is preferred for programme exchange. The actual emulsion position should be indicated on the leader and on the label of the film (NORMAL for the preferred position or REVERSED).

3.8 Film splices should be carried out in accordance with appropriate international or national standards.

3.9 A leader for protection and identification should be attached to each film.

3.9.1 The minimum length of the protection and identification leader should be 3 m (10 ft).

3.9.2 The minimum information given on the identification leader should be as follows:

— name of sending organization,

— title of programme,

— code word (see § 1),

— position of emulsion (see § 3.7),

— total programme duration and picture frequency,

— total number of reels,

— reel number,

— duration or length of the film on the reel.

Further information may be given, such as: production methods used, e.g. telerecording or a code word according to ISO.

3.9.3 The identification leader should have the same type of base and perforations as the film to which it is attached. Leaders should be attached to the film in such a manner that the emulsion on both leader and film is on the same side.

3.9.4 Combined picture and sound films should have a dotted line marked upon the frame line one frame ahead of the start of the first picture or the beginning of the sound, whichever is the earlier (Fig. 1).

3.9.5 In the case of a SEPMAG film type, a synchronization mark corresponding to the dotted line on the picture film (see § 3.9.4) should also be placed on the magnetic film.

3.10 Films may be transported on flanged reels or on flangeless hubs as specified in the appropriate international or national standards. The boxes in which films are transported should be identified with labels carrying the same information as the corresponding film leader (see § 3.9.2).

3.11 The diameter of a flanged reel or the outer diameter of the film on a flangeless hub should not exceed 380 mm (15 in.). It is desirable that 16-mm films exceeding 300 m (1000 ft) in length should be on flanged reels.

3.12 Hubs and reels intended for films with magnetic sound stripe should be made of non-magnetic material.

4. Special standards for certain types of film

4.1 *COMOPT types*

The preferred types of optical sound tracks are variable area, bilateral or double bilateral.

The nominal optical sound-recording characteristic for 35-mm and 16-mm film is that which produces a constant modulation of its optical transmission as a function of frequency within the given frequency range on the sound track of the film when a sine-wave signal of constant amplitude is fed into the input of the recording channel.

The corresponding nominal reproducing characteristic is that which produces a sine-wave output signal whose level is independent of frequency when reproducing a sound-track recorded with the nominal recording characteristic specified above (see Annex).

4.1.1 *35 COMOPT*

The location and dimensions of picture frames and sound-track should conform with appropriate international standards (ISO Recommendation R73 and ISO Recommendation R70).

The useful audio-frequency range is 40 Hz to 8000 Hz.

4.1.2 *16 COMOPT*

The location and dimensions of picture frames and sound-track should conform with appropriate international standards (ISO Recommendation R359 and ISO Recommendation R71).

The useful audio-frequency range is 50 Hz to 5000 Hz.

4.2 *16 COMMAG*

4.2.1 The dimensions and position of the magnetic sound stripes should be as given in Fig. 2.

4.2.2 The sound record should be in advance of the centre of the corresponding picture by 28 ± ½ frames.

4.2.3 The magnetic stripe should be on the side of the film that faces the light source of a projector arranged for direct projection onto a reflecting-type screen.

4.2.4 The maximum additional thickness due to the magnetic coating should be 0·02 mm (0·0008 in.).

4.2.5 If a balancing magnetic stripe is used, it should have the same thickness as the main magnetic stripe. No sound recording should be made on the balancing stripe.

4.2.6 The recording and reproducing characteristics should be those standardized by the IEC (Publication 94) for magnetic tape at a speed of 19·05 cm/s (7·5 in./s) except for the time constant t_1.

Two standards are currently in use (see Report 294-2, § 6), having:

— a time constant of 100 μs;

— a time constant of 50 μs.

Some Administrations and recognized private operating agencies consider a time constant of 70 μs to be a suitable compromise for the international exchange of programmes (see Report 294-2, § 6).

4.3 *16 SEPMAG 16 SEPDUMAG*

4.3.1 Two standards for SEPMAG are used (see Note):

— a 5·1 mm (0·2 in.) centre track, according to ISO Recommendation R890, commonly used in Europe (see Fig. 3);

— a 5·1 mm (0·2 in.) edge track, according to ISO Recommendation R891, commonly used in the United States of America and Canada. (This type of track can, if necessary, be reproduced by a magnetic head designed for 16 COMMAG or 16 SEPDUMAG track No. 2).

4.3.2 16 SEPDUMAG should conform to Fig. 3 (see also Note to § 2.2).

Note. — A new sound track standard proposed for 16 SEPMAG and 16 SEPDUMAG having a centre track and an edge track both of 4·0 mm (0·158 in.) width may in the future lead to a single 16 SEPMAG standard which can at the same time be used for 16 SEPDUMAG (see Note under § 2.2) (see Report 294-2, § 7).

4.3.3 The COM and SEP types should not be combined. That is to say, if one or more sound tracks are provided on a separate film, only the SEP tracks should be used for reproduction.

4.3.4 The recording and reproducing characteristics should be those standardized by the IEC (Publication 94) for magnetic tape for a speed of 19·05 cm/s (7·5 in./s) except for the time constant t_1.

Two standards are currently in use, having:

— a time constant of 100 μs,

— a time constant of 50 μs.

Some Administrations and recognized private operating agencies consider a time constant of 70 μs to be a suitable compromise for the international programme exchange (see Report 294-2, § 6).

4.4 *35 COMMAG*

4.4.1 The dimensions and position of the magnetic sound stripe should be as given in Fig. 5.

4.4.2 The sound record should be 28 ± ½ frames behind the centre of the corresponding picture.

4.4.3 The magnetic sound stripe should be on the side of the film towards the lens of a projector arranged for direct projection on to a reflecting screen.

4.4.4 If a balancing stripe is used, it should have the same thickness as the magnetic sound stripe. No sound recording should be made on the balancing stripe.

4.4.5 The recording and reproducing characteristics should be those standardized by the IEC for magnetic tape for a tape speed of 38·1 cm/s (15 in./s) having a time constant t_1 of 35 μs (see IEC Publication 94).

4.5 *35 SEPMAG and 35 SEPDUMAG*

4.5.1 The second (sound) film should be a standard 35-mm magnetic film.

4.5.2 The position of the sound tracks is specified in ISO Recommendation R162. If only one sound track is used, it should be track No. 1 (see Fig. 4). If a second sound track is used, it should be track No. 2.

4.5.3 The COM and SEP types should not be combined. That is to say, if one or more sound tracks are provided on a separate film, only the SEP tracks should be used for reproduction.

4.5.4 The recording and reproducing characteristics should be those standardized by the IEC for magnetic tape for a tape speed of 38·1 cm/s (15 in./s) having a time constant t_1 of 35 μs (see IEC Publication 94).

ANNEX

The preferred method of measurement of the recording characteristic of optical sound tracks is by reference to the output signal of an ideal replay chain. (An ideal replay chain is defined as having a signal output proportional to the modulation of the optical transmission of the sound-track when this is scanned by a slit whose width is negligible in relation to the shortest recorded wavelength on the film.) This condition may be verified by measuring the modulation of the optical transmission of the film by means of a microdensitometer adjusted to have a slit-width which is negligible in relation to the shortest recorded wavelength on the film.

The preferred method of calibrating a reproducing chain is by means of a standard test film recorded with a number of audio sine-wave frequencies producing constant modulation of the optical transmission.

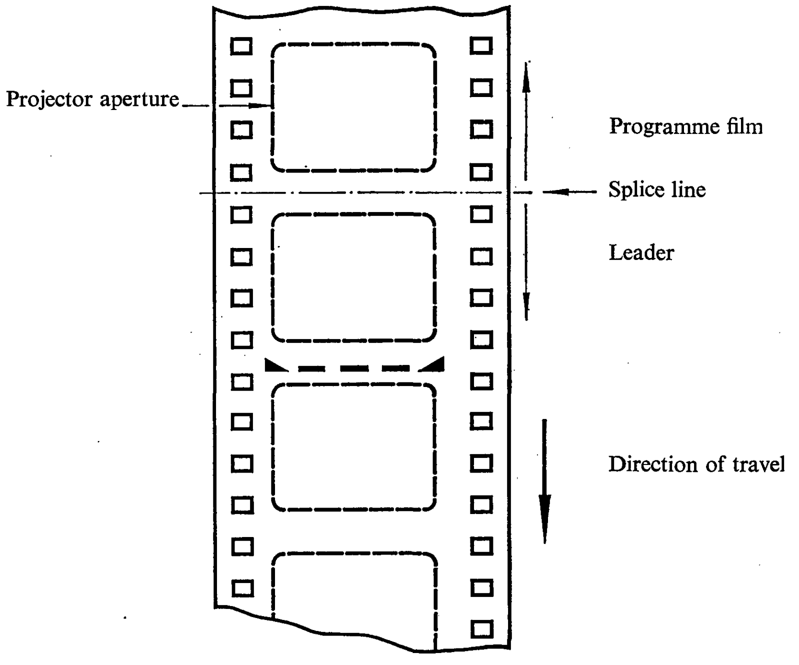
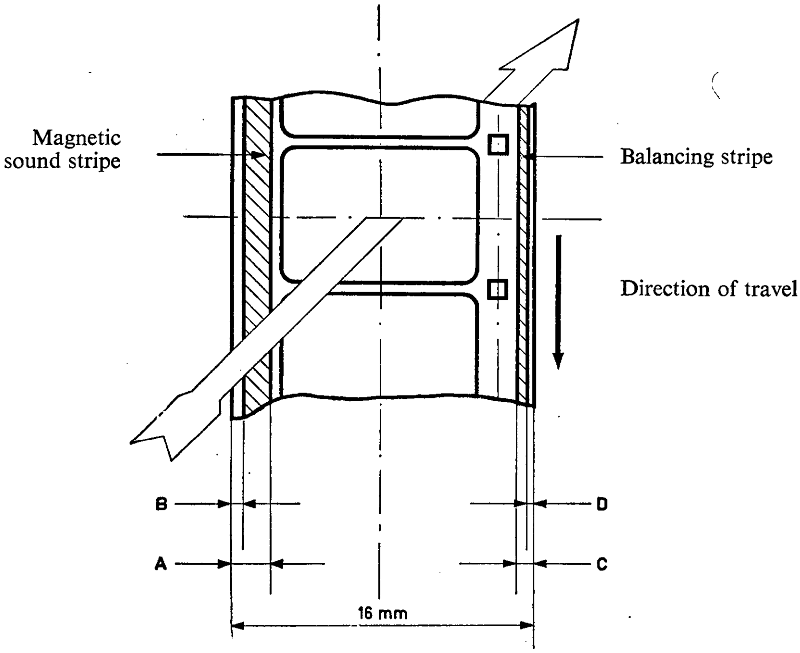


FIGURE 1

End of film identification leader—35 mm film

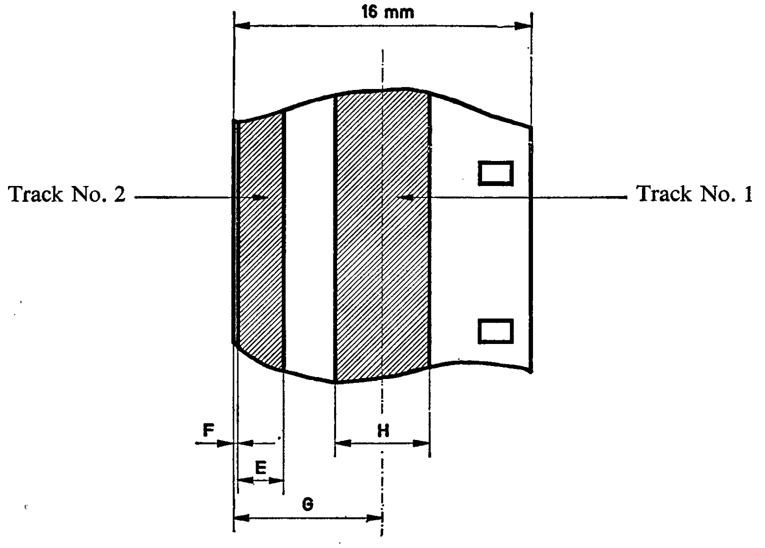


Dimensions

	Millimetres	Inches
A	2·5 $^{+0·15}_{-0}$	0·100 $^{+0·004}_{-0·002}$
B	0·127 max.	0·005 max.
C	0·8 $^{+0}_{-0·1}$	0·031 $^{+0}_{-0·005}$
D	0·05 max.	0·002 max.

FIGURE 2

Sound recording on film type 16 COMMAG

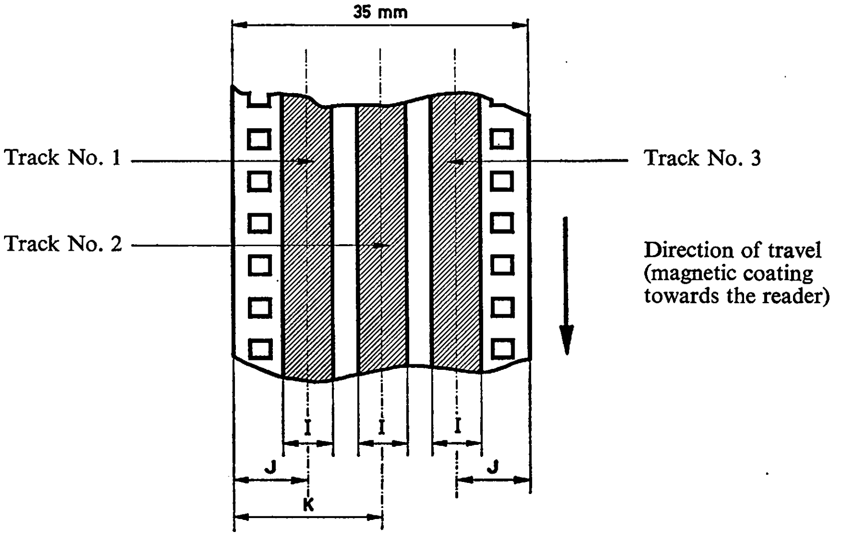


Dimensions

	Millimetres	Inches
E	2·54 $^{+0·127}_{-0}$	0·100 $^{+0·005}_{-0}$
F	0·127 $^{+0}_{-0·127}$	0·005 $^{+0}_{-0·005}$
G	8·00 ±0·10	0·315 ±0·004
H	5·08 ±0·05	0·200 ±0·002

FIGURE 3

Sound recording on film type 16 SEPDUMAG

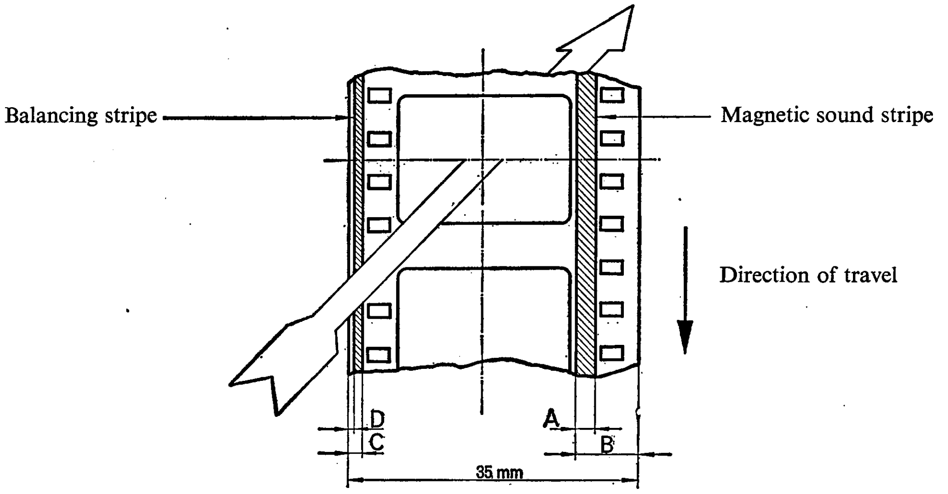


Dimensions

	Millimetres	Inches
I	5·08±0·05	0·200±0·002
J	8·61±0·10	0·339±0·004
K	17·50±0·10	0·689±0·004

FIGURE 4

Sound recording on film type 35 SEP with one or more tracks



Photographic emulsion in front, magnetic coating behind

Dimensions

	Millimetres	Inches
A	2·5 $^{+0·1}_{-0}$	0·100 ±0·002
B	7·6 $^{+0·1}_{-0}$	0·300 $^{+0·002}_{-0}$
C	1·8 $^{+0}_{-0·25}$	0·07 $^{+0}_{-0·01}$
D	0·25 max.	0·01 max.

FIGURE 5

Sound recording on film type 35 COMMAG

RECOMMENDATION 407-2

INTERNATIONAL EXCHANGE OF RECORDED SOUND PROGRAMMES

The C.C.I.R. (1951 – 1953 – 1956 – 1959 – 1963 – 1966 – 1970)

UNANIMOUSLY RECOMMENDS

that the international exchange of recorded sound programmes, both monophonic and stereophonic, between broadcasting organizations should be by means of:

1. magnetic recording on tape as specified in Recommendation 261-2;

2. recording on discs of Types III, IV, V and VI as specified in the current edition of IEC Publication 98.

RECOMMENDATION 408-2 *

STANDARDS OF SOUND RECORDING ON MAGNETIC TAPE FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES

The C.C.I.R. (1951 – 1953 – 1956 – 1959 – 1963 – 1966 – 1970)

UNANIMOUSLY RECOMMENDS

that monophonic and stereophonic recordings on magnetic tape for the international exchange of programmes should be made in accordance with the current edition of IEC Publication 94, with the following amendments:

1. **Speed of tape**

Primary speeds: { 38·1 cm/s (15 in./s) nominal value
19·05 cm/s (7½ in./s) nominal value

Note. — A secondary speed is under study.

2. **Width of tape**

6·25 mm ± 0·05 mm (0·246 ± 0·002 in.)

3. **Strength of tape**

The tape should be suitable for use on a machine exerting a maximum (transient) stress of 10 Newtons.

4. **Maximum diameter of a full spool**

For Type I: 290 mm (11·5 in.)
(In France the maximum diameter is 270 mm)

For Type II: 267·5 mm (10·5 in.)

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* This Recommendation also replaces Recommendation 261-1.

5. Beginning of a programme

The beginning of a recorded programme should be identified by one of the following methods:

— if there is a non-magnetic identification strip at the beginning of the reel, the trailing end of the strip should precede the beginning of the programme by 1 s;

— if there is no identification strip, a visual marker (preferably metal-coated) should be stuck to the uncoated side of the tape 1 s before the beginning of the programme.

The length of tape corresponding to 1 s is calculated for the nominal tape speed.

6. Programme identification

The information requested in Publication 94 of the IEC should be supplemented by the following:

MONO or STEREO

MAXIMUM RECORDED LEVEL (in nWb/m).

RECOMMENDATION 409-2

MEASUREMENT OF WOW AND FLUTTER IN RECORDING EQUIPMENT AND IN SOUND REPRODUCTION

(Study Programme 1A-1/10)

The C.C.I.R. (1956 – 1963 – 1966 – 1970)

UNANIMOUSLY RECOMMENDS

1. that the method of measurement giving the peak value is preferable; *

2. that use should be made of the " preferred frequency " of 3150 Hz in accordance with ISO Recommendation R266 (3000 Hz may also be used);

3. that the measurements made, with or without the appropriate weighting, should include all flutter and wow frequencies in the range 0·2 Hz to at least 200 Hz;

4. that measurements should preferably be made on one element only of the system (either the recorder or the reproducer, but not both) under such conditions that the wow and flutter in the remaining portions of the system is negligible;

   in those cases when this condition cannot be fulfilled, a recorder-reproducer may be measured by recording a 3150 Hz test frequency, and subsequently reproducing this record and measuring the total wow and flutter. In no case shall wow and flutter be measured while simultaneously recording and reproducing;

5. that the following measuring conditions should always be indicated, viz.:
   — peak or r.m.s. value,
   — weighted or unweighted value,
   — system measured (reproducer only, recorder only or complete recording-reproducing system);

6. that, when measuring the peak value, the measuring equipment should have the following specifications:

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* This method is being studied by the IEC.

6.1 *Response curve for the weighted measurement*

This curve is derived from Table II and is given in Fig. 1. It gives a value which corresponds closely to the subjective impression.

6.2 *Dynamic characteristics (with weighting)*

For short unidirectional deviations of the frequency of measurement (rectangular pulses of duration *A*) with a repetition rate of 1 Hz, the meter should indicate the percentage *B* of the reading obtained with a sinusoidal frequency-modulation of 4 Hz having a peak-to-peak deviation equal to the frequency swing of the pulse:

TABLE I

Duration of impulse, *A*, (ms)	10	30	60	⩾ 100
Indication, *B*, (%)	21±3	62±6	90±6	100±4

The return time should be such that, when applying pulses of 100 ms duration with a repetition rate of 1 Hz, the meter should indicate 36% to 44% between the pulses;

6.3 *Indication*

The meter should measure peak-to-peak values, but the reading should indicate the wow in per cent (%) or parts per thousand of the figure corresponding to one half the peak-to-peak value.

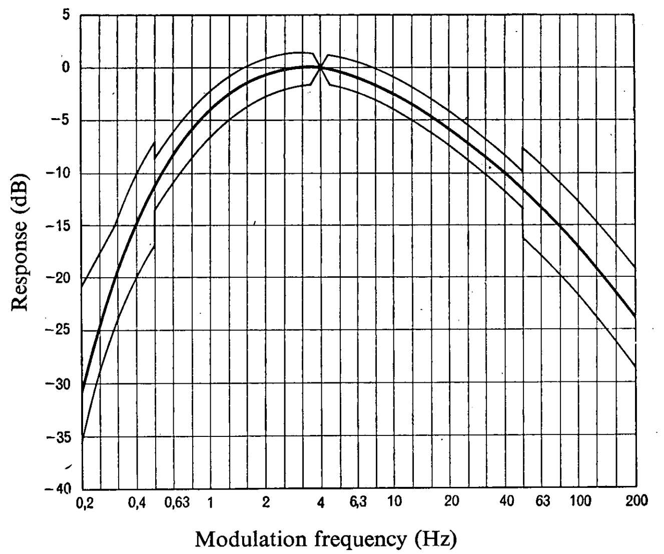

FIGURE 1

Frequency-response curve of weighting network

TABLE II

Frequency response for weighting network

Frequency (Hz)	Attenuation (dB)	Tolerances on attenuation (dB)
0·2	−30·6	At 0·2 Hz : +10; −4
0·315 0·4	−19·7 −15·0	From 0·315 to 0·5 Hz : ±4
0·63 0·8 1·0 1·6 2·0	− 8·4 − 6·0 − 4·2 − 1·8 − 0·9	From 0·5 to <4 Hz : ±2
4·0	0	At 4 Hz : 0
6·3 10 20 40	− 0·9 − 2·1 − 5·9 −10·4	From >4 to 50 Hz : ±2
63 100 200	−14·2 −17·3 −23	From 50 to 200 Hz : ±4

RECOMMENDATION 468

MEASUREMENT OF AUDIO-FREQUENCY NOISE IN BROADCASTING AND IN SOUND-RECORDING SYSTEMS

(Study Programme 2A/10)

The C.C.I.R. (1970)

UNANIMOUSLY RECOMMENDS

that for the measurement of audio-frequency noise in broadcasting and in sound-recording systems, to give results best in agreement with subjective assessment, a weighting network having a frequency response characteristic in accordance with Fig. 1 should be used.

Note. — This Recommendation replies to § 2 of Study Programme 2A/10, which asks what characteristics should be recommended for these measuring sets. Further studies are necessary before a reply to § 1 of the Study Programme can be given.

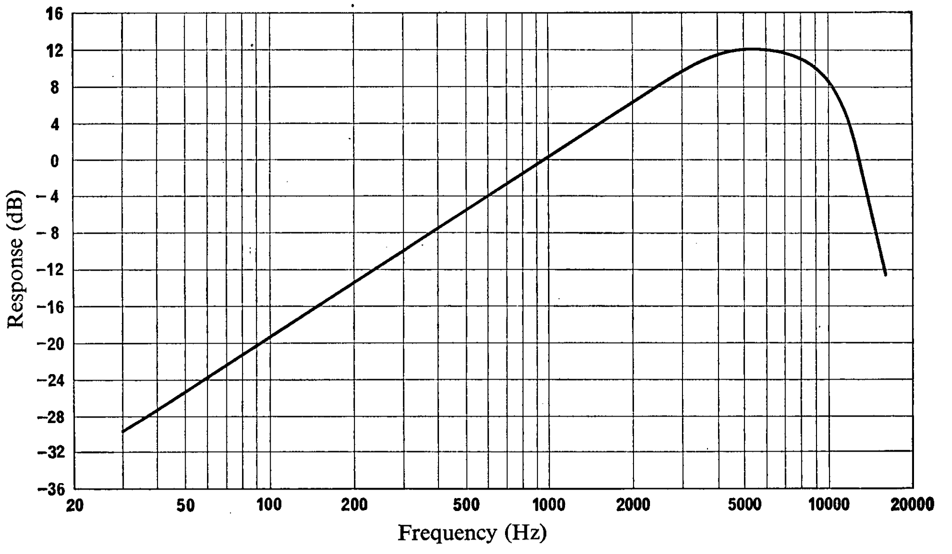

FIGURE 1

Frequency-response characteristic of the weighting network

TABLE I

Frequency response for the characteristic shown in Fig. 1.

Frequency (Hz)	Response (dB)
31·5	−30·2
63	−24
100	−20
200	−13·9
400	− 7·9
800	− 1·9
1 000	0
2 000	5·8
3 000	8·8
4 000	10·7
5 000	11·8
6 300	12·3
7 100	12·0
8 000	11·2
9 000	10·0
10 000	8·1
12 000	2·2
14 000	− 5·5
16 000	−12·5

RECOMMENDATION 469

STANDARDS FOR THE INTERNATIONAL EXCHANGE OF TELEVISION PROGRAMMES ON MAGNETIC TAPE

The C.C.I.R. (1970)

UNANIMOUSLY RECOMMENDS

that the magnetic recordings used for the international exchange of television programmes should meet the following standards:

1. Recording systems

1.1 Recordings on magnetic tape of television programmes which are the subject of international exchange should be made by means of the technique that makes use of a rotating wheel bearing four video heads moving in a direction transverse to the tape motion (transverse track recording).

1.2 These recordings should be carried out in accordance with one of the following classes of television systems:

— 625 lines — 50 fields per second

— 525 lines — 60 fields per second

(see Reports 463 and 468).

2. Dimensions of the magnetic tape for television recording

The magnetic tape used for television recording should conform to the following dimensions:

width : $50{\cdot}80 \begin{smallmatrix} +\ 0{\cdot}00 \\ -\ 0{\cdot}10 \end{smallmatrix}$ mm ($2{\cdot}000 \begin{smallmatrix} +\ 0{\cdot}000 \\ -\ 0{\cdot}004 \end{smallmatrix}$ in.)

maximum thickness : 0·038 mm (0·0015 in.)

maximum curvature: 1·1 mm in 1 m (0·043 in. in 39·4 in.)

Note. — The curvature should be measured by constraining the tape to lie in a plane under zero tension, and by positioning a straight-edge of the specified length as shown in Fig. 1. The maximum deviation of the tape edge from the straight-edge should be taken as the curvature.

3. Spools

3.1 The dimensions of the spools shall be as specified in Fig. 2 and in Tables I and II. *

3.2 The spool shall be so constructed that any cross-section through its axis shall lie within the shaded area of Fig. 2, including any axial displacement of the flanges during rotation.

3.3 Bosses, ribs or raised designs are permitted on the outside surface of the flanges provided they do not extend beyond the shaded area shown on Fig. 2, when the spool rotates on its axis.

3.4 The surface of the flanges from *B* to *L* shall lie between the planes defined by *H* and *J*.

3.5 Outside surfaces of the flanges between diameters *K* and *L* including flange-fastening members shall not extend beyond the surfaces defined by dimension *M*.

* The dimensions in millimetres were derived from the dimensions in inches which represent the primary standard. The dimensions in millimetres are rounded off in such a way as not to impair interchangeability.

TABLE I

Spool dimensions

Dimensions (see Fig. 2)	Millimetres	Inches	Degrees
A	$76{\cdot}2\ {}^{+\,0{\cdot}1}_{-\,0{\cdot}0}$	$3{\cdot}000\ {}^{+\,0{\cdot}004}_{-\,0{\cdot}000}$	
B	See Table II	See Table II	
C (1)	$114{\cdot}0\ {}^{+\,0{\cdot}5}_{-\,0{\cdot}0}$	4·500 ± 0·010	
D	$82{\cdot}5\ {}^{+\,0{\cdot}1}_{-\,0{\cdot}0}$	3·250 ± 0·002	
E	$5{\cdot}6\ {}^{+\,0{\cdot}15}_{-\,0{\cdot}00}$	$0{\cdot}219\ {}^{+\,0{\cdot}006}_{-\,0{\cdot}000}$	
F	*E*/2	*E*/2	
G			120 ± 0·1
H	0·65 max.	0·025 max.	
J	2·5 max.	0·098 max.	
K	91·5 min.	3·600 min.	
L	153 min.	6·000 min.	
M	56·2 ± 0·1	2·212 ± 0·003	

(1) Exclusive of friction ring. Friction rings, if provided, shall be such as not to impair spool performance.

TABLE II

Dimension B (Fig. 2)

Millimetres	Inches
165·1 ± 0·25	6·500 ± 0·010
203·2 ± 0·25	8·000 ± 0·010
266·7 ± 0·25	10·500 ± 0·010
317·5 ± 0·25	12·500 ± 0·010
355·6 ± 0·25	14·000 ± 0·010

TABLE III

Approximate spool capacities

Size of spool		Approximate capacity		Approximate maximum playing time (minutes)	
Millimetres	Inches	Metres	Feet	625-line 50 fields/s systems	525-line 60 fields/s systems
165	6·5	225	750	9	10
203	8	500	1650	21	22
267	10·5	1100	3600	46	48
318	12·5	1700	5540	71	74
356	14	2200	7230	92	96

3.6 The hub surfaces defined by dimension M shall be parallel within $\pm 0{\cdot}0004$ mm per mm ($\pm 0{\cdot}0004$ in. per in.) ($\Delta M/M \leqslant 0{\cdot}0004$).

3.7 It is desirable that both flanges have regularly spaced holes, which extend to the hub periphery and are of such size at this point as to facilitate threading.

3.8 Spools shall be symmetrical and shall mount from either side.

3.9 The outside cylindrical surface of the hub (diameter C) shall be concentric with the central bore (diameter A) within a tolerance of $\pm 0{\cdot}05$ mm (0·002 in.), i.e. the maximum eccentricity shall be 0·025 mm (0·001 in.).

3.10 The outside diameter of the flanges (diameter B) shall be concentric with the centre bore of the hub (diameter A) within a tolerance of $\pm$ 0·4 mm (0·015 in.), i.e. the maximum eccentricity shall be 0·2 mm (0·008 in.).

3.11 The maximum taper of the outside cylindrical surface of the hub (diameter C) shall be 0·04 mm (0·0016 in.).

3.12 A minimum distance of 5 mm (0·2 in.) shall be allowed between the outside radius of the tape stack and the periphery of the spool. Approximate spool capacities are given in Table III.

4. Speeds of the tape and the video head wheel

4.1 The nominal linear speed of the tape and the nominal rotational speed of the video head wheel should conform to Table IV.

TABLE IV

Nominal speed	625-line, 50-fields/s systems	525-line, 60-fields/s systems
Nominal linear tape speed	39·7 cm/s (15·625 in./s)	38·1 cm/s (15 in./s)
Nominal rotational speed of wheel	250 rev/s	240 rev/s

5. Vacuum guide radius and position

5.1 The relative position of the vacuum guide and the video head wheel should be such that a line drawn from the axis of rotation of the wheel through the centre of curvature of the vacuum guide intersects the tape at the mid-point of its width (Fig. 3).

5.2 The radius of the vacuum guide should be:

$$26{\cdot}248 \begin{smallmatrix} +\ 0{\cdot}000 \\ -\ 0{\cdot}013 \end{smallmatrix} \text{ mm } \left(1{\cdot}0334 \begin{smallmatrix} +\ 0{\cdot}0000 \\ -\ 0{\cdot}0005 \end{smallmatrix} \text{ in.}\right)$$

5.3 The distance E (eccentricity) between the axis of rotation O of the wheel and the centre of curvature C of the vacuum guide should be adjusted to be equal to the amount by which the guide radius departs from its nominal value. The centre of curvature of the vacuum guide should lie between the axis of rotation of the wheel and the vacuum guide.

Note. — The above specification is based on a nominal tape thickness of 0·0356 mm (0·0014 in.) and on a radius of rotation of the head-pole tips of 26·236 mm (1·0329 in.) (minimum) to 26·304 mm (1·0356 in.) (maximum).

6. Position of the recorded tracks

6.1 The position and dimensions of the video-, audio-, control- and cue-tracks should be in accordance with Fig. 4 and Table V.

6.2 Each video track should not deviate from a straight line by more than 0·025 mm (0·001 in.).

TABLE V

Dimensions of video-, audio-, cue- and control-tracks

Dimensions (see Fig. 4)	Millimetres	Inches	Degrees
A	0·00 min. 0·10 max.	0·000 min. 0·004 max.	
B	1·02 min. 1·24 max.	0·040 min. 0·049 max.	
C	1·47 min. 1·57 max.	0·058 min. 0·062 max.	
D	1·98 min. 2·16 max.	0·078 min. 0·085 max.	
E	2·21 min. 2·39 max.	0·087 min. 0·094 max.	
F	29·2 ± 1·3	1·15 ± 0·05	
G	48·31 min. 48·62 max.	1·902 min. 1·914 max.	
H	48·79 min. 49·02 max.	1·921 min. 1·930 max.	
I	50·50 min. 50·70 max.	1·988 min. 1·996 max.	
J (1)	1·5875 ± 0·0015	0·06250 ± 0·00006	
K	0·240 min. 0·265 max.	0·0095 min. 0·0105 max.	
L	*J*/4	*J*/4	
M (2)	0·000 ± 0·005	0·0000 ± 0·0002	
α			90°33′ ± 3′

(1) For satisfactory editing of tapes the closer tolerance specified (± 0·1 %) is necessary. The measurement is carried out on a length of tape under zero tension, corresponding to a suitable number of *J* intervals. The imperfect dimensional stability of the tape may result in variations of the measured value of *J*, which are not negligible as compared to the specified tolerance.

(2) Error produced by axial displacement of the pole tips.

7. Position of tape neutral plane and related guides

7.1 The centre-line of the tape located in the plane defined by guides X and Y (neutral plane) shall be parallel to the axis of rotation of the video head wheel, and 23·0 ± 0·5 mm (0·905 ± 0·020 in.) from this axis (dimension *C*, Fig. 6); the plane thus defined (plane P of Fig. 6) shall be perpendicular to the tape neutral plane.

7.2 The first guiding element encountered by the tape after it leaves the vacuum guide (tape output guide Y) shall be located 190·5 mm ± 6·3 mm (7·50 ± 0·25 in.) from the plane of rotation of the pole tips (dimension *B* in Fig. 5).

7.3 The last guiding element encountered by the tape as it approaches the vacuum guide (tape input guide X) shall be located symmetrically with respect to the plane of rotation of the pole tips and the tape output guide Y (dimension *A* in Fig. 5).

7.4 Any lack of parallelism between the centre-line of the tape in the neutral plane and the axis of rotation of the video head wheel, and/or any lack of symmetry between input and output guides with respect to the plane of rotation of the pole tips, will cause a curvature of the recorded track and/or an error in the angle of the track which must not exceed the limits for these parameters.

Note. — When all other factors (such as vacuum guide radius, vacuum level, tape tension, ambient temperature and humidity) are the same as they were when the tape was recorded,

— a tape recorded at the minimum dimension for *C* and played back on a reproducer having the maximum dimension for *C* will have a residual velocity error of less than 2 ns peak-to-peak (during a 64 μs interval);

— a tape recorded with maximum allowable track curvature caused by lack of parallelism and/or lack of symmetry, as described in § 7.4, and played back on a reproducer having no dimensional errors, will have a residual velocity error of less than 0·4 ns peak-to-peak (during a 64 μs interval);

8. Specification for video recording

8.1 The video information should be recorded in the form of a radio-frequency signal linearly frequency-modulated by the video-frequency signal.

8.2 The instantaneous modulation frequencies, corresponding to reference video levels, should be as indicated in the Table below:

TABLE VI (1)

Reference video-frequency levels	625-line, 50-fields/s systems		525-line, 60-fields/s systems	
	Low band	High band	Low band	High band
Synchronizing (MHz)	4·95	7·16	4·28	7·06
Blanking (MHz)	5·50	7·80	5·00	7·90
White (MHz)	6·80	9·30	6·80	10·00

(1) The Table is based on the ratios of picture signal amplitude to synchronizing signal amplitude indicated in § 2.3 of Recommendation 421-2.

The tolerance on the indicated frequencies should be ± 0·05 MHz in all cases.

8.3 Recordings of colour signals should only be made using the " high-band " modulation frequencies indicated in Table VI.

8.4 The time constants of the video-frequency emphasis network (see Report 466) are defined in Table VII.

TABLE VII

Time constant (ns)	625-line, 50-fields/s systems		525-line, 60-fields/s systems	
	Low band	High band	Low band	High band
t_1	53	240	26·4	240
t_2	160	600	132	600

9. Specification for programme-sound recording

9.1 The television sound signal should be recorded on the audio track only (see § 10.1).

9.2 The audio-frequency recording should be so positioned along the length of the tape as to lead the associated video information by 235 ± 1·3 mm (9·25 ± 0·05 in.).

9.3 The maximum recorded flux at medium wavelengths is 250 $^{+60}_{-0}$ nWb/m (r.m.s.) (this maximum flux corresponds to the subjective overload level for average video-tapes).

9.4 The audio-frequency recording and reproducing characteristics should be those described in IEC Publication 94 for a speed of 38·1 cm/s, with a time constant of 35 µs.

Note. — Many countries use an additional time constant of 2000 µs.

10. Specification for cue-signal recording

10.1 Utilization of the cue track should normally be left to the ultimate user (see Study Programme 24A/10).

10.2 The cue recording should be so positioned along the length of the tape as to lead the associated video information by 235 ± 1·3 mm (9·25 ± 0·05 in.).

11. Specification for the recording of field synchronizing and control signals

11.1 The position of the field-synchronizing signal on the video tracks should be as indicated in Fig. 4.

To achieve satisfactory splicing between different recorded tapes, the tolerance on dimension *F* should be ± 0·1 mm or ± 0·004 in.

11.2 The signal recorded on the control track consists of a train of editing pulses superimposed on a tracking signal.

11.3 The editing pulses identify the position on the tape of the field-synchronizing signal of " second fields " for 625-line, 50 fields/s signals and " first fields " for 525-line, 60 fields/s signals (see Report 308-2), as detailed in § 11.4.

For 625-line, 50-fields/s signals, the editing pulse rate should be 25 Hz for low band recording; and 12·5 Hz for high band recordings.

For SECAM recordings, the editing pulses should identify the position on the tape of the field-synchronizing signal of second fields beginning with a line having the chrominance modulated by the signal D'_B.

For PAL recordings, the editing pulses should identify the position on the tape of the field-synchronizing signal of second fields in the PAL four-field sequence (Report 468).

For recordings of 525-line, 60-fields/s signals the repetition rate of the editing pulses should be 30 Hz. *

11.4 For 625-line, 50-fields/s signals (or 525-line, 60-fields/s signals), the editing pulse should be positioned as indicated in Fig. 4, so that the centre line of the recorded pulse and the extended centre line of the area between the 5th and 6th video tracks before (or the 2nd and 3rd video tracks after) the track containing the field-synchronizing signal indicated in § 11.3 intersect within ± 0·05 mm (± 0·002 in.) at the reference edge of the tape (Fig. 4).

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* To assist in certain restricted types of NTSC colour tape editing, alternate frame pulses may be omitted. Since omission of alternate frame pulses may result in slightly lengthened machine lock-up time in tape replay, the originating organization may wish to obtain prior agreement before programme exchange.

11.5 The amplitude of the editing pulse current should be a minimum of 150% of the peak-to-peak amplitude of the control signal current in the record head.

11.6 The polarity of the pulse with respect to the control signal should be as shown in Fig. 4.

11.7 The wave form of the control signal current flowing through the record head should be sinusoidal.

11.8 For 625-line, 50-fields/s signals (or 525-line, 60-fields/s signals) the frequency of the control signal should be five times (or four times) the field frequency of the television signal.

11.9 The amplitude of the control signal current flowing through the record head should be such that the tape is driven to the verge of saturation. This amplitude can be established by the method described in Annex I.

11.10 For 625-line, 50-fields/s signals (or 525-line, 60-fields/s signals) the control signal recording should be so positioned that a point of maximum record current and the extended centre line of the area between the 5th and the 6th video tracks before (or the 2nd and the 3rd video tracks after) the track containing the field-synchronizing pulse coincide within ± 0·025 mm (0·001 in.) at the reference edge of the tape (Fig. 4).

11.11 The point of maximum record current coinciding with the edit pulse should be one that immediately follows an area on the control record to which a south-seeking pole of a compass will be attracted. The location of these attraction areas is indicated in Annex I.

12. Mechanical tape splices

12.1 The number of tape splices should be kept to a minimum.

12.2 The splices should conform to the applicable national or international standards.

13. Tape leaders

13.1 Tape leaders should be as follows:

Duration (s)	Picture	Sound
10	None	None
60 minimum	Alignment signal	Audible tone at reference level (1)
15	Programme identification (2)	Spoken identification
8	Either black level or cue	Either silence or cue
2	Black level	None

(1) The reference level used is 9 dB below the level corresponding to the maximum flux indicated in § 9.3.
(2) The programme identification indicated should be either in picture or in sound or preferably in both.

13.2 A minimum of 30 s at black level without any sound signal shall be recorded immediately following the end of the programme.

13.3 The synchronizing and control signal shall be continuous from at least 10 s and preferably from 25 s before the beginning of the programme, to the end of the run-out signal specified in § 13.2.

14. Presentation of recordings

14.1 Recordings of a single programme of up to 90 min duration should preferably be on one spool.

14.2 Separate programmes should always be on separate spools.

15. Programme identification

15.1 At least the following information should be supplied with each recorded television tape:

- — name of the organization which made the recording;
- — title of programme, or title, sub-title and episode number;
- — total number of spools, and number of the spool in the sequence when the programme is contained on more than one spool;
- — library number (reference number) of programme or of tape;
- — total playing-time, and playing-time of the programme material recorded on the tape;
- — line and field system (625/50 or 525/60);
- — recording standard (" high band " or " low band ");
- — indication of the colour system, for colour recordings.

15.2 The information required in § 15.1 should be provided in at least one of the official languages of the I.T.U.

15.3 The information required in § 15.1 should be supplied on a label affixed to the programme spool, and to the container.

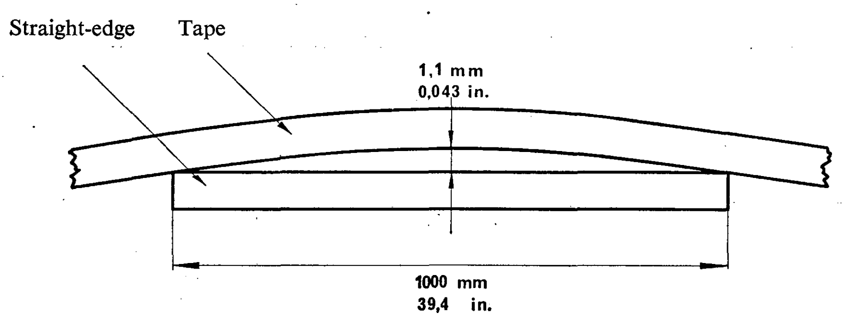

FIGURE 1

Measurement of the curvature of magnetic tape

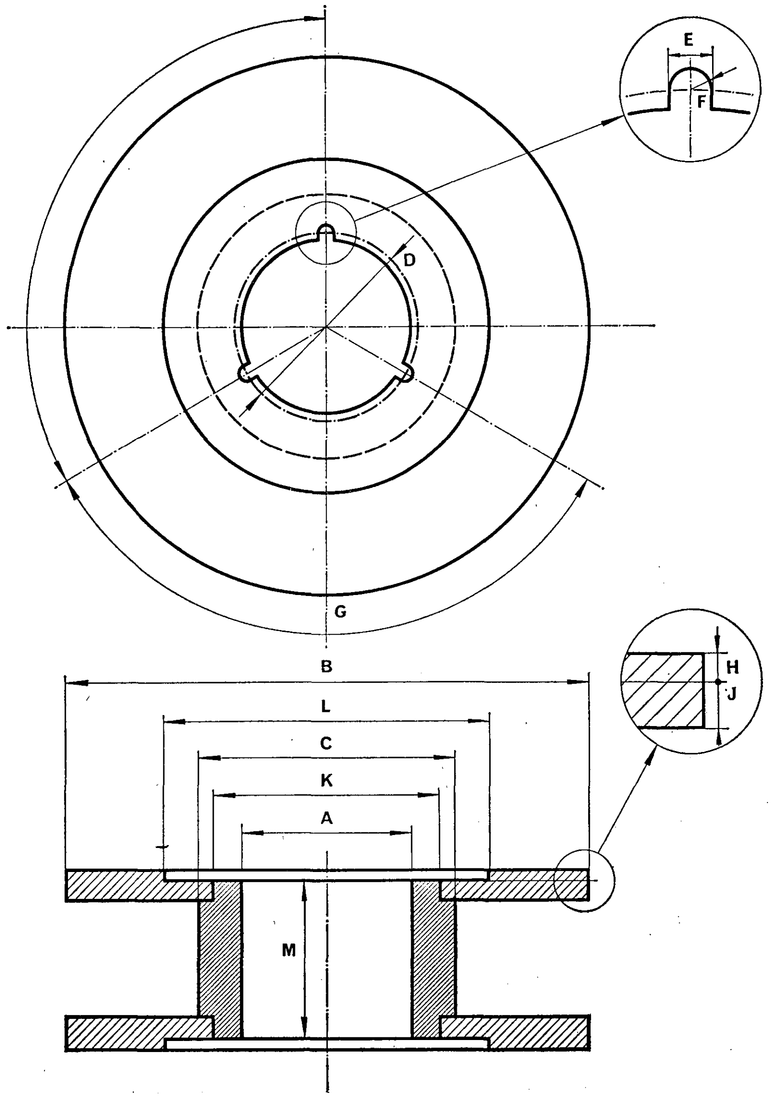

FIGURE 2

Spools for television tape

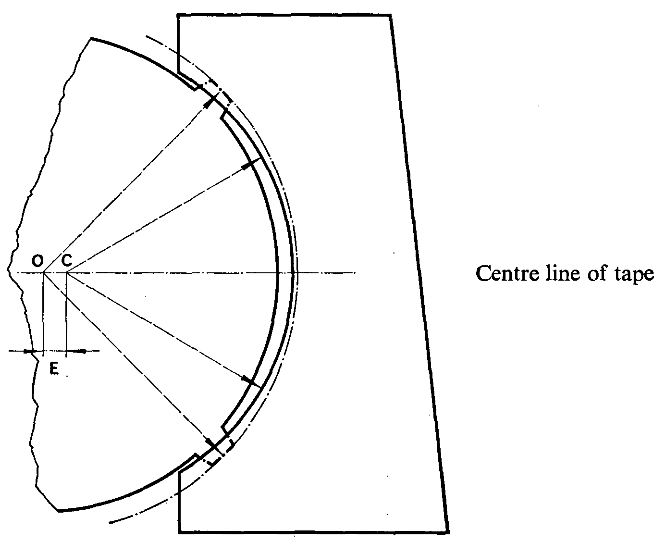

FIGURE 3

Relative position of vacuum guide and video head wheel

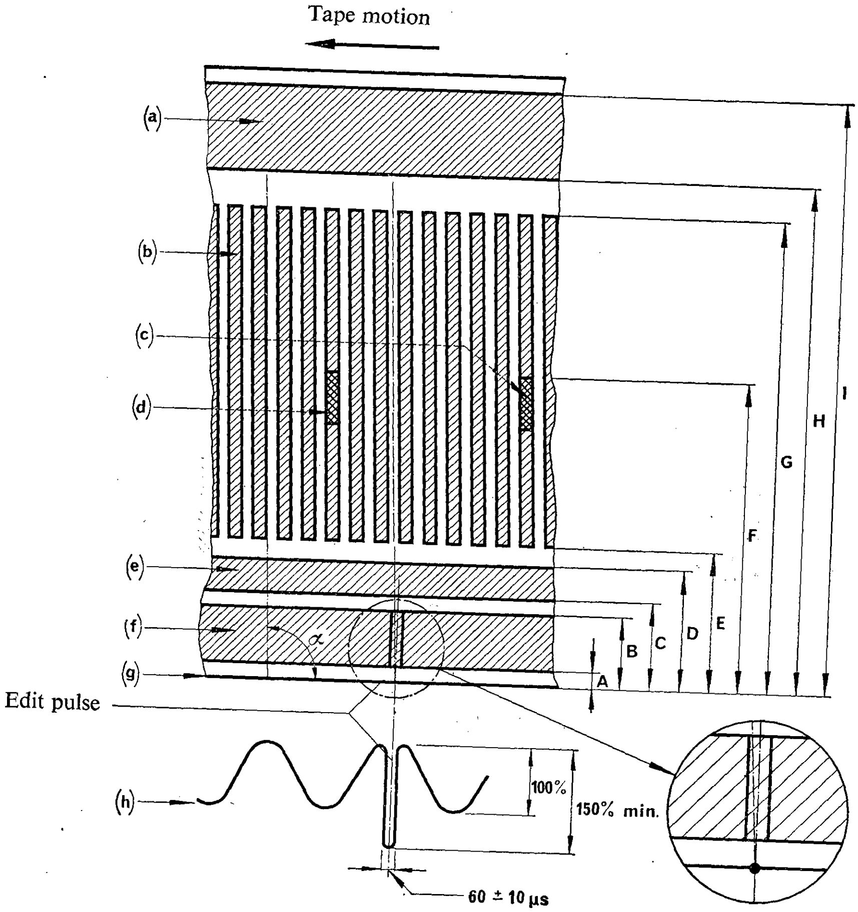

FIGURE 4

Positions of video-, audio-, cue- and control-tracks

(a) Audio track
(b) Video tracks
(c) Start of field-synchronizing signal
625 lines – 50 fields/s
(d) Start of field-synchronizing signal
525 lines – 60 fields/s
(e) Cue track
(f) Control track
(g) Reference edge of tape
(h) Waveform of the record current in the control-track head

Note. — The magnetic coating of the tape faces the observer.

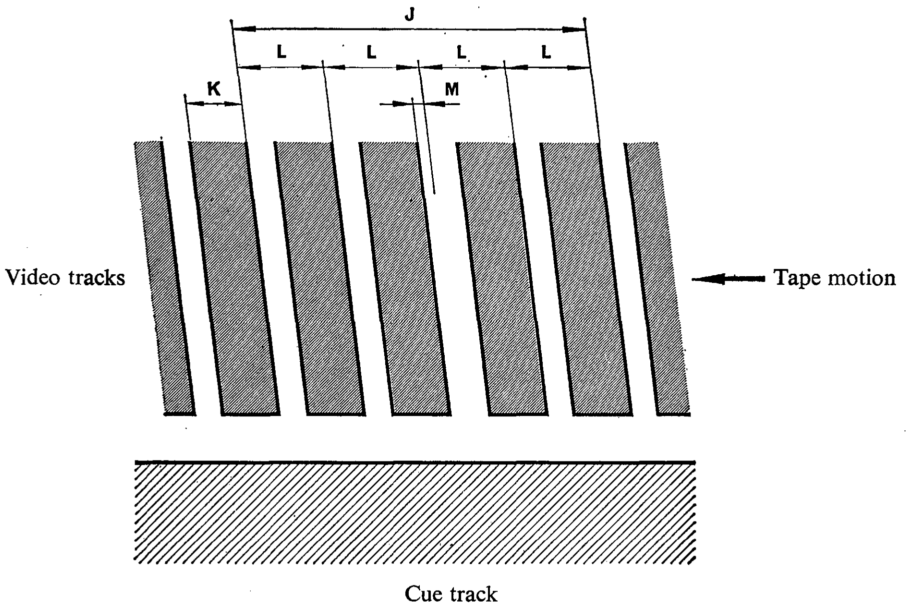

FIGURE 4*a*

Detail from Figure 4

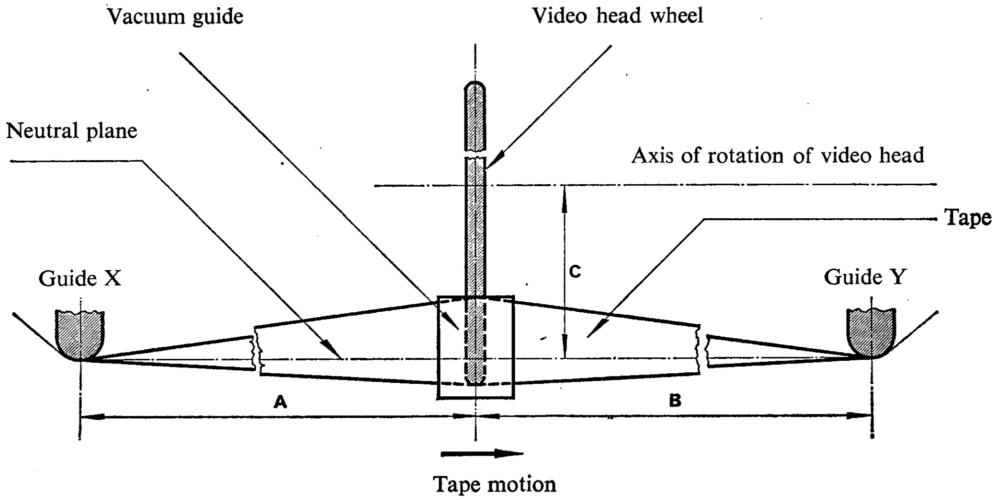

FIGURE 5

Configuration of the tape at the head wheel

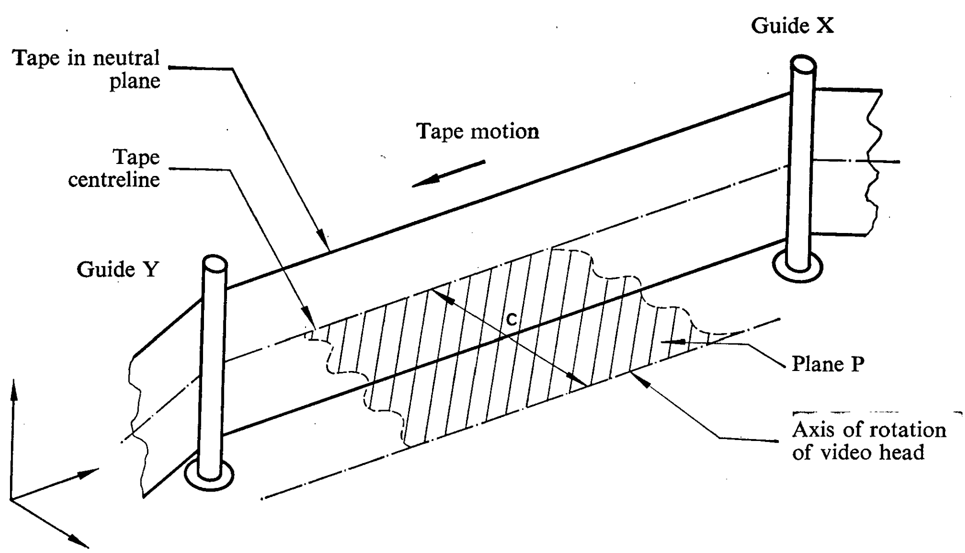

FIGURE 6

Position of tape neutral plane and wheel axis

ANNEX I

1. Determination of the verge of saturation of the control track

The verge of saturation is considered to be the condition where the recorded flux waveform is just noticeably flattened on its peak. This flattening of the flux peaks results in an inflection in the playback voltage waveform in the zero axis crossing region. The verge of saturation can thus be determined by increasing the record current until a just perceptible inflection occurs in the zero axis crossing region of the playback voltage (see Fig. 7).

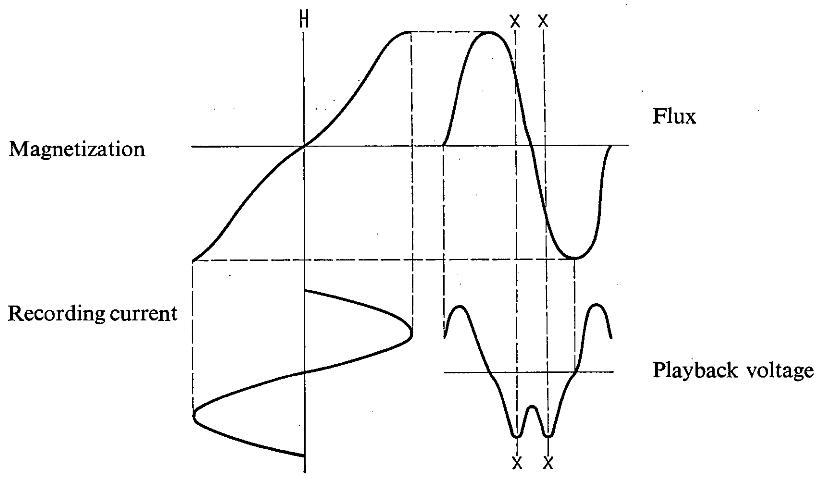

FIGURE 7

Relation between recording current and playback voltage

2. Areas of attraction of a compass needle

The areas to which a compass needle is attracted do not coincide with the point of maximum recording current. The compass will be attracted to two areas (X, as shown in Fig. 7) adjacent to the point where the recording current crosses the zero axis. The two areas will appear as bars when the record is made visible with carbonyl iron or an equivalent material.

ANNEX II

EXAMPLE OF A STANDARDIZED LABEL FOR TELEVISION TAPE-RECORDING

The European Broadcasting Union has drawn up a standardized design of a label containing all the information envisaged in § 15.1 of this Recommendation. The label has been designed to be stuck to the reel, but its size (8 × 5 cm) is such that it can be affixed to the cans in which the tapes are kept.

Fig. 8 is a drawing of this label. The printed text, reading from top to bottom, indicates the following:

- the name of originating service; the blank space to the right of the symbol of this organization is reserved for internal use by the organization which has recorded the programme;
- reference number of the programme or tape;
- complete title of programme;
- total number of spools, and a number denoting the order of the spools, when the programme is recorded on more than one;
- playing-time of the programme material recorded on the tape;
- indication of standards and, if necessary, of the colour system used; this information can be conveyed simply by placing a tick in the squares relating to the various printed details;
- remarks; the first line is provided for putting down any additional information; the second line is reserved for internal use by the organization which has recorded the programme.

The text printed on the label must be in at least one of the official languages of the E.B.U. This information is in both English and French for those organizations whose only official language is either English or French.

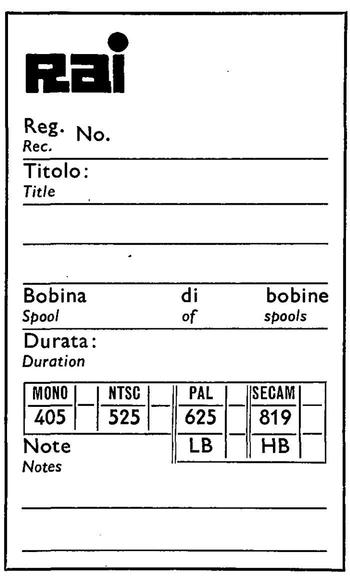

FIGURE 8

Drawing of a label conforming to the E.B.U. standard.

REPORT 79-2 *

MEASUREMENT OF THE CHARACTERISTICS OF SOUND SIGNALS RECORDED ON MAGNETIC TAPE

(1956 - 1966 - 1970)

The experts of the competent committees of the IEC have adopted the short-circuit tape flux as a characteristic parameter of the recorded signal. The C.C.I.R. considers that this parameter should be used in accordance with the Recommendations which will be contained in IEC Publication 94.

It is felt that the procedures for measuring this flux are sufficiently known—see, in particular, Doc. X/6 (U.S.A.), 1966-1969 and the reference below.

1. McKnight, J. G. Absolute flux and frequency response characteristics in magnetic recording; measurements, definitions and standardization. *J. Audio Eng. Soc.*, **15**, 254-272 (July, 1967).

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* This Report, which was adopted unanimously, constitutes a final reply to Question 3/X, study of which is now terminated.

REPORT 292-2 *

MEASUREMENT OF PROGRAMME LEVEL IN SOUND BROADCASTING

(1963 – 1966 – 1970)

Question 151 asked, " by what methods and by means of what equipment should the programme level be controlled in connection with recording, reproduction, and transmission over lines or radio links? "

As far as transmission over lines or radio links is concerned, C.C.I.T.T. Recommendation J.14 applies and should be respected.

As far as recording and reproduction are concerned, there is no need for special methods of measurement different from those used for general purposes in broadcasting.

Methods of measuring programme levels in sound broadcasting have been under consideration by the C.C.I.R. for many years and, as was indicated in Reports 33 and 117, it has not been possible to reach agreement on the use of a single type of meter.

Report 117 noted that it was desirable to retain Question 151, because research was in progress and new information might become available. Since then only one new proposal has emerged, namely, that two meters specified by the O.I.R.T. should be adopted as international standards. These meters, however, are rather similar to the peak-type meters that have hitherto been discussed in the C.C.I.R. and there seems to be little likelihood that they could be universally adopted. It is not possible, therefore, to do more than state the present practices and Table I shows the fundamental characteristics of the meters that are recommended at present by the C.C.I.T.T., together with those recommended by the O.I.R.T.

This Report is, as far as possible, a reply to Question 151.

Nevertheless, it may become desirable, at some time in the future, to establish a new Study Programme for the whole problem of the measurement and control of the dynamic range of sound programmes.

Note 1. — In France, a meter has been standardized similar to that defined in item (2) of Table I.

Note 2. — In the Netherlands, a meter has been standardized (Type N.R.U.—ON 301) similar to that defined in item (4) of Table I.

Note 3. — In Italy, a programme meter with the following characteristics is in use:

— Rectifier characteristic: $n = 1$ (see Note 4).

— Time to reach 99% of final reading: approx. 20 ms.

— Integration time: approx. 1·5 ms.

— Time to return to zero: approx. 1·5 s from 100% to 10% of the reading in the steady state.

Note 4. — The number given in the column is the exponential n in the formula $V_{out} = (V_{in})^n$ applicable for each half-cycle.

Note 5. — The " integration time " was defined by the C.C.I.F. as the " minimum period during which a sinusoidal voltage should be applied to the instrument for the pointer to reach to within 0·2 N or nearly 2 dB of the deflection which would be obtained if the voltage were applied indefinitely ". A logarithmic ratio of 2 dB corresponds to 79·5% and a ratio of 0·2 N to 82%.

* This Report was adopted unanimously.

TABLE I

Principal characteristics of the various instruments used for monitoring the volume or peaks during programme transmissions

Type of instrument	Rectifier characteristics (Note 4)	Time to reach 99% of final reading (ms)	Integration time (ms) (Note 5)	Time to return to zero (value and definition)
(1) C.C.I.T.T. — " Speech voltmeter " British type 3 (S.V.3) identical to the speech power meter of the A.R.A.E.N.	2	230	100 (approx.)	equal to the integration time
(2) C.C.I.T.T. — V.U. meter (United States of America) C 16.5 — 1954 A.S.A. (Note 1)	1·0–1·4	300	165 (approx.)	equal to the integration time
(3) C.C.I.T.T. — Speech power meter of the " S.F.E.R.T. " volume indicator	2	around 400-650	200	equal to the integration time
(4) C.C.I.T.T. — Peak indicator for programme transmission used by the B.B.C. (B.B.C. Peak Programme Meter) (Note 2)	1	around 12	10 (1)	3 seconds for the pointer to fall 26 dB
(5) C.C.I.T.T. — Maximum amplitude indicator used by the Federal Republic of Germany (Type U21)	1	around 80	5 (approx.)	1 or 2 seconds from 100% to 10% of the reading in the steady state
(6) O.I.R.T. — Programme level meter		less than 300 ms for meters with pointer indication and less than 150 ms for meters with light indication	4 to 10	1·5 to 2 seconds from " 0 dB " point at 30% of the length of the operational section of the scale

(1) The figure 4 ms that appeared in previous editions was actually the time taken to reach 80% of the final reading with a d.c. step applied to the rectifying/integrating circuit. In a new and somewhat different design of this programme meter, using transistors, the performance on programme remains substantially the same as that of the earlier versions and so does the response to an arbitrary, quasi-d.c. test signal but the integration time as here defined is about 20% greater at the higher meter readings.

REPORT 293-2 *

AUDIO-FREQUENCY PARAMETERS FOR THE STEREOPHONIC TRANSMISSION AND REPRODUCTION OF SOUND

(Study Programme 15B/10)

(1963–1966–1970)

1. Introduction

Extensive studies have been carried out in several countries with regard to Study Programme 15B/10, which is concerned with the study of the subjective aspects of stereophonic sound transmission and reproduction.

2. Overall tolerances of the quality parameters for stereophony

2.1 During the Interim and the Final Meetings of the Study Group, Palma de Mallorca, 1968 and Geneva, 1969, the following documents were considered:

2.1.1 Doc. X/13 (E.B.U.), 1966–1969, describes the results of further examination of the audio-frequency characteristics that affect the stereophonic reproduction of sound; it also gives the specifications for the overall stereophonic quality and furthermore, the tolerances which must be met by international transmission circuits and national distribution networks for stereophonic programmes.

2.1.2 Doc. X/60 (O.I.R.T.) and Doc. X/208 (O.I.R.T.), 1966–1969, draw attention to O.I.R.T. draft Recommendation 43-II. This contains the " preferred overall values " for the high-quality monophonic and stereophonic sound transmission chain parameters. " Marginal subjective values " are given for information only.

An attempt was made in these documents to arrive at a unique specification for the overall stereophonic quality.

During the discussion which took place in Study Group X, a table was drafted indicating the tolerance values to be aimed at (Study Programme 15B/10, § 3).

Although it was recognized that the quality should not only be specified for the whole of a stereophonic chain, but also for its several sections, it was only possible to define the tolerances for the overall stereophonic quality.

2.1.3 Docs. X/148 (U.S.A.) and X/157 (U.S.A.), 1966–1969, describe some techniques for achieving monophonic compatibility from stereophonic discs and tapes. Study Programme 15C/10 was adopted.

2.1.4 Doc. X/209 (O.I.R.T.), 1966–1969, is a draft O.I.R.T. Report containing amendments and supplements to O.I.R.T. Recommendation 33/1 for parameters of stereophonic recordings intended for the international exchange of programmes. It is intended to give an indication of the existing trends on this matter.

2.1.5 Doc. X/199 (Sweden), 1966–1969, gives the results of listening tests with different types of programme to determine signal-to-noise ratios for conditions when noise becomes perceptible and when it becomes disturbing. It suggests that the overall value for signal-to-noise ratio of 55 dB given in Table I may not be high enough for high quality stereophonic broadcasting with certain types of programme.

* This Report was adopted unanimously.

2.2 *Significance of the tolerances*

The values shown in Table I are the overall tolerances that must be applied in a complete stereophonic transmission chain, to ensure good quality reproduction. They therefore apply in principle to a transmission chain extending from the microphone output to the input of the loudspeakers, i.e. including studio equipment, links, and the stereophonic transmitter and receiver. The E.B.U. also considers a magnetic tape recorder to be part of the transmission chain. The receiver considered is a monitoring receiver such as may be used in the studio for subjective monitoring of the broadcast programme.

The E.B.U. and the O.I.R.T. are aware that, in certain cases, the limitations of the performance of the equipment will imply the possibility of relaxing tolerances; however, it is desirable for future technological progress to accept the overall tolerances indicated.

2.3 *General conditions of measurement*

Values of individual parameters should be measured with standard operational conditions at individual points in the transmission chain.

Ideal transmitter to receiver radiation, propagation and receiving conditions are assumed in the path between the transmitter and the receiver.

2.4 *Notes on the individual parameters*

2.4.1 *Bandwidth*

The E.B.U. and the O.I.R.T. particularly stress the danger of limiting the bandwidth of the *S* signal in those parts of the transmission chain where that signal is effectively present.

2.4.2 *Amplitude/frequency response*

It is preferable for the acceptable *A* and *B* channel tolerance limits to be defined by a profile. Fig. 1 shows these tolerances referred to a level of 0 dB. The area within this profile can be used as a mask within which an acceptable response curve should fit.

Below 40 Hz and above 15 kHz, the curve should have a falling characteristic, the slope of which has yet to be determined.

2.4.3 *Difference in level between the A and B channels*

The acceptable tolerance for the difference in level between the *A* and *B* signals is also given in the form of a profile (Fig. 2). The tolerated difference in level for a particular frequency is, therefore, equal to the maximum deviation between the absolute values of the amplitude/frequency curves of the *A* and *B* channels, both of which should, nevertheless, fall within the profile specified in § 2.4.2.

2.4.4 *Difference in phase between the A and B channels*

The proposed tolerance profile for this parameter is given in Fig. 3.

2.4.5 *Linear crosstalk between the A and B channels*

The proposed tolerance profile for this parameter is given in Fig. 4.

2.4.6 *Weighted signal-to-noise ratio*

This proposed figure represents the difference in level between the noise measured after the psophometric noise weighting network, and a signal whose amplitude corresponds to the maximum permissible frequency deviation.

2.4.7 *Intermodulation*

It is not possible at this stage to specify the tolerances for intermodulation in a stereophonic system. There are several methods of measurement that can be used for evaluating certain non-linear interaction phenomena, and the E.B.U. and the O.I.R.T. consider that further study is necessary.

2.4.8 *Harmonic distortion*

This tolerance applies to the most unfavourable result obtained by applying to the stereophonic system, at maximum level, the following three combinations of signals: $A = B$, $A = -B$, A or $B = 0$.

2.4.9 *Non-linear crosstalk*

Further studies are necessary to establish exact tolerance for this parameter.

The E.B.U. considers, nevertheless, that identical tolerances could be assigned to non-linear crosstalk and harmonic distortion.

3. Table of quality tolerances in stereophony

The Table summarizes the tolerances applicable to the quality parameters of stereophonic reproduction.

The figures given in the overall values column represent the limits that should be applied at the end of the transmission chain for good quality stereophonic reproduction.

The diagrams following the Table show some of these tolerances in graphical form.

TABLE

	Parameters and signals (1)	Frequencies	Overall values
1	Bandwidth *A*, *B*, *M* and *S*		40 Hz to 15 kHz
2	Boundaries for the amplitude/frequency response (Fig. 1) *A* and *B* (dB)	40 Hz to 125 Hz 125 Hz to 630 Hz 630 Hz to 1250 Hz 1250 Hz to 10 kHz 10 kHz to 15 kHz	2 to – 3 1 to – 1 0·5 to – 0·5 1 to – 1 2 to – 3
3	Level difference (2) (Fig. 2) *A* and *B* (dB)	1 kHz 40 Hz to 125 Hz 125 Hz to 10 kHz 10 kHz to 15 kHz	1 3 1·5 3
4	Phase difference (2) (Fig. 3) *A* and *B* (degrees)	40 Hz 40 Hz to 200 Hz 200 Hz to 4 kHz 4 kHz to 15 kHz 15 kHz	90° oblique segment (Fig. 3) 45° oblique segment (Fig. 3) 90°
5	Linear crosstalk (2) (Fig. 4) *A* and *B* (dB)	40 Hz to 300 Hz 300 Hz to 4 kHz 4 kHz to 15 kHz	oblique segment 6 dB per octave – 30 oblique segment 6 dB per octave
6	Weighted signal-to-noise ratio *A*, *B* and *M* (dB)		55 (3)
7	Intermodulation *A* and *B* (dB)		not yet available
8	Harmonic distortion *A*, *B* and *M* (dB)	40 Hz to 125 Hz 125 Hz to 5 kHz 5 kHz to 15 kHz	– 34 – 40 (4)
9	Non-linear crosstalk (dB)		not yet available

(1) *A* is the signal on the left and *B* the signal on the right. $M = \frac{1}{2}(A + B)$ and $S = \frac{1}{2}(A - B)$.

(2) This concerns only differences of volume, phase or of the linear crosstalk, which are introduced unintentionally between the *A* and *B* channels owing to imperfections in the transmission chain.

(3) The value of 55 dB is adequate in most cases. However, for some types of programme (e.g. piano music) it would be desirable to increase this value by about 10 dB. The signal-to-noise ratio is defined on the basis of the psophometric curve, C.C.I.T.T. Recommendation P.53. It must be re-established after the adoption of a new Recommendation on the method for measuring psophometric noise. Study Programme 2A/10, concerning this problem, is under study.

(4) The values resulting when measuring with a distortion meter in the frequency range 5 kHz to 15 kHz can contain not only harmonics of the measuring frequency but also combination frequencies which are generated in the stereophonic receiver. Further investigations are necessary to determine these tolerances.

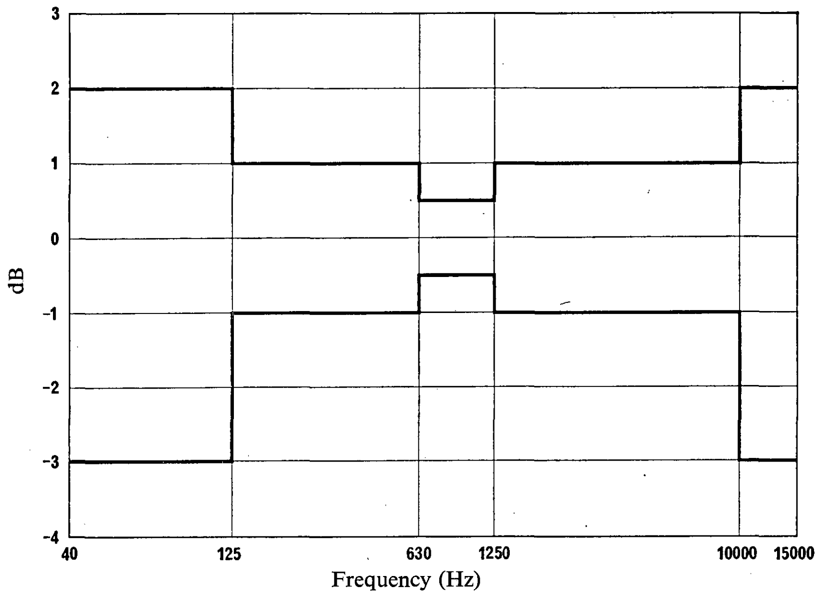

FIGURE 1

Limits for the amplitude/frequency response of the A and B channels

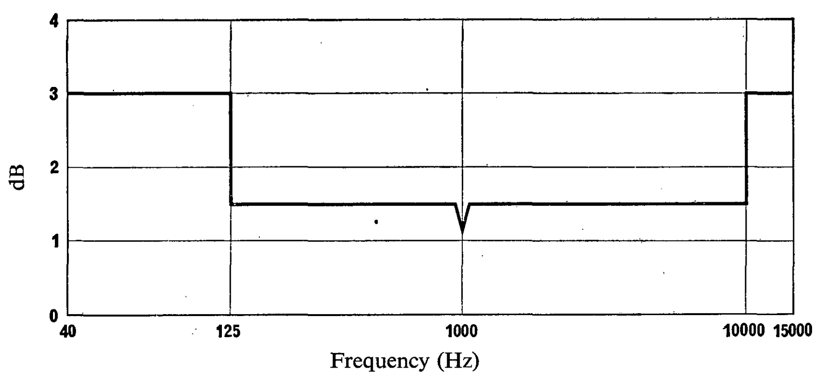

FIGURE 2

Difference in level between the A and B channels

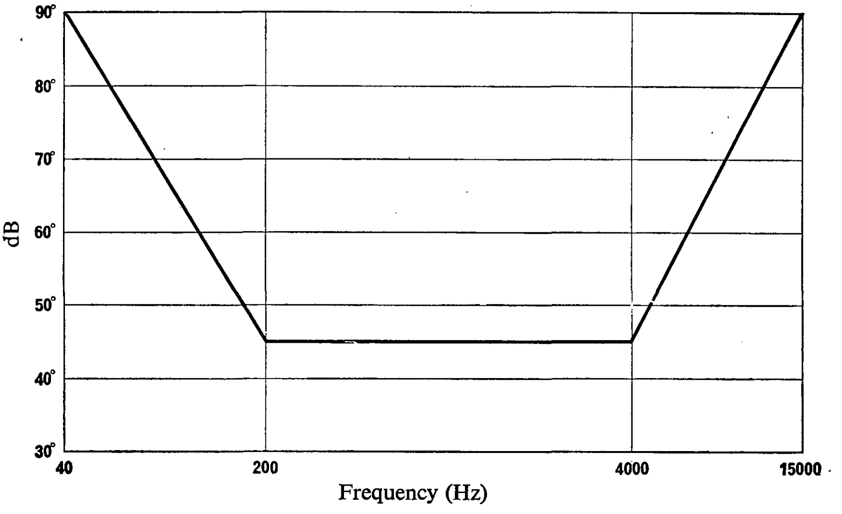

FIGURE 3

Phase difference between the A and B channels

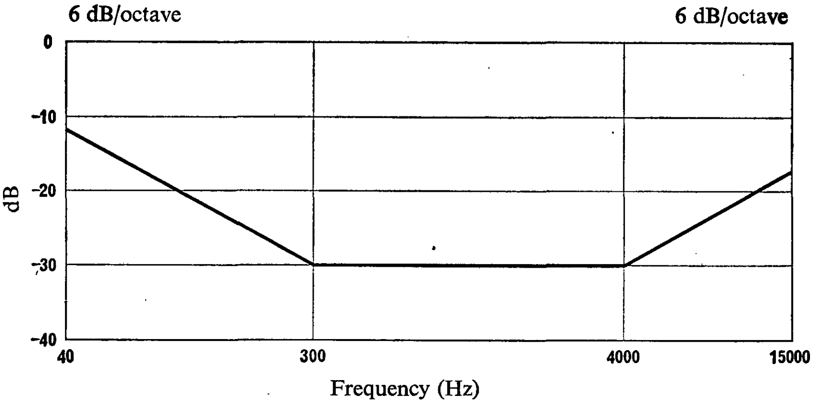

FIGURE 4

Linear crosstalk between the A and B channels

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23. Doc. X/59 (U.S.S.R.), 1963–1966.
24. Doc. X/147 (O.I.R.T.), 1963–1966.
25. Doc. X/60 (O.I.R.T.), 1966–1969.
26. Doc. X/148 (U.S.A.), 1966–1969.
27. Doc. X/157 (U.S.A.), 1966–1969.
28. Doc. X/199 (Sweden), 1966–1969.
29. Doc. X/209 (O.I.R.T.), 1966–1969.

REPORT 294-2 *

STANDARDS FOR THE INTERNATIONAL EXCHANGE OF MONOCHROME AND COLOUR TELEVISION PROGRAMMES ON FILM

(Recommendation 265-2)

(1970)

1. At the Final Meeting, Geneva, 1969, it was decided to combine into a single text the revised contents of Recommendation 264-1 and Recommendation 265-1. This decision was taken to permit a more coherent treatment of the standardization of all film types intended for the international exchange of television programmes, and to permit some rearrangement of the text to accommodate the addition of recommendations concerning colour films. " Colour " has been added to the title of the Recommendation.

2. Question 16/11 ** refers to characteristics of monochrome film, while Question 21/11 *** refers to characteristics of colour film. Although it has not been possible to supply answers to all items of either Question, it has been possible to include new information, especially concerning the recommended characteristics for colour films. Agreement has been reached regarding colour film densities and colour balance. It is hoped that Questions 16/11 and 21/11 may be combined during the period 1970–1973.

3. Further contributions are necessary to permit complete answers to Question 16/11 and Question 21/11, especially with regard to the following matters:
   - monochrome telecine reproducer characteristics;
   - colour telecine reproducer characteristics (Doc. X/159 (Canada), 1966–1969, supplies preliminary information on this subject);
   - visual assessment criteria for colour films intended for television, including specifications for screen brightness and ambient light levels in the viewing room. (Doc. X/159 (Canada), 1966–1969, also supplies preliminary information on this subject.)

4. Question 20/11 **** asks about the problem of recording, on colour film, live television programmes or programmes recorded on magnetic tape. Report 469 summarizes systems currently in use for this purpose. Further contributions, including necessary technical parameters, will be required to answer Question 20/11.

5. Question 17/11 ***** refers to optical sound recording standards. Some parts of this question are answered in Recommendation 265-2. However, more information is needed before recommendations on sound volume compression and expansion characteristics are possible.

6. Question 19/11 ****** refers to standards for magnetic sound recording and reproducing on 16 mm film. The responses received to Question 21/X showed a great diversity of opinions. The following documents deal with this matter: X/147 (U.S.A.), X/160 (Canada), X/164 (France), X/186 (Italy), X/205 (Federal Republic of Germany), 1966–1969. European practice has generally been to use a time constant of 100 μs as specified in former editions of Recommendation 265. In some countries, such as the United States of America and Canada, a

* This Report was adopted unanimously.

** This Question replaces Question 5/X of former Study Group X.

*** This Question replaces Question 23/X of former Study Group X.

**** This Question replaces Question 22/X of former Study Group X.

***** This Question replaces Question 6/X of former Study Group X.

****** This Question replaces Question 21/X of former Study Group X.

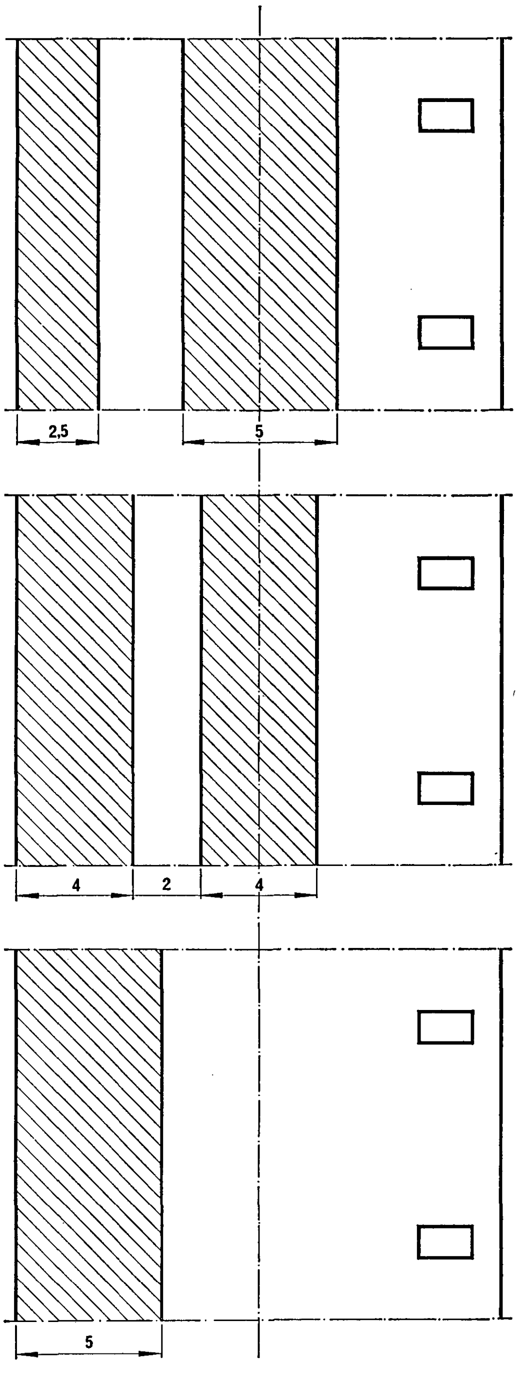
reproducing characteristic is used which at high frequencies approximates to 50 μs and incorporates an audio-frequency attenuation with a time constant of about 1200 μs. The French Administration proposes to use a 50 μs time constant with no audio-frequency attenuation. A number of Administrations and recognized private operating agencies have proposed the adoption of a time constant of 70 μs as a compromise standard. (A time constant of 70 μs has been recommended by the IEC for use with 6·25 mm (¼ in.) tape at 19·05 cm/s (7·5 in./s)).

A trend towards the use of time constants lower than 100 μs is apparent with modern materials. Further contributions are awaited to enable the best technical decision leading to the definition of a single recording and reproducing characteristic to be made.

7. To reduce the number of existing 16 SEPMAG and 16 SEDUMAG variants, a proposal described in Doc. X/163 (France) defines a compatible two-track recording on 16 mm magnetic film having a centre track and an edge track of the same width, 4·0 mm (0·158 in.). This track system merits future consideration. Fig. 1 illustrates the proposal contained in Doc. X/163 (France).

8. The matter of synchronizing film reproducers with other sound and picture sources is dealt with in Report 468.

9. Cueing leaders are currently under active study, especially by ISO Technical Committee 36 and by the E.B.U. It is considered unwise to change present C.C.I.R. wording on the subject at this time, except for clarification of the specification for cue marks on SEPMAG films.



C.C.I.R. standard

Proposed new compatible two-track system

United States PH 22.97 standard (conforms to ISO R 891)

FIGURE 1

Standards for 16 mm sound tracks

REPORT 398-1 *

MEASUREMENT OF AUDIO-FREQUENCY NOISE IN BROADCASTING AND IN SOUND RECORDING SYSTEMS

(Study Programme 2A/10)

(1966 – 1970)

The aim of Study Programme 2A/10 is to determine whether mean, r.m.s. or peak value measurements should be used to evaluate audio noise in broadcasting and in sound recording systems, and also to determine the appropriate measuring set characteristics.

Report 398 provided information on the subject and partly answers the problems posed by the Study Programme. Report 292-2 is also relevant.

This Report is based on further information given in Docs. X/22 (United Kingdom), X/23 (Federal Republic of Germany) and X/61 (O.I.R.T.), 1966–1969.

Doc. X/22 concludes from the results of tests with combinations of meters and weighting networks already in use or proposed that measurements of audio-frequency noise best in agreement with subjective assessment should be made with a modified version of the instrument devised by Niese [1] in conjunction with a weighting network having a frequency response characteristic shown in Fig. 1 of the document.

Doc. X/23 also concludes that a weighting network having the same frequency response characteristic as that shown in Doc. X/22, Fig. 1, should be used but considers that the question of the dynamic characteristic of the measuring instrument requires further study.

Doc. X/61 is also in agreement with the weighting network curve shown in Doc. X/22, Fig. 1, and suggests that instruments operating in accordance with the Niese-type meter and DIN 45 405 responses produce results which are in best agreement with the subjective assessment of noise.

Weighting network curve A, adopted by IEC Technical Committee 29 and ISO Technical Committee 43, which is intended for the measurement of acoustic noise, is not considered suitable for the measurement of audio-frequency noise in broadcasting and sound recording systems, as in this case it is the effect of the noise on the programme rather than the loudness of the noise itself which is important. Moreover, tests have shown that the curve A produces large errors when measuring certain types of noise, particularly with wide bandwidth circuits having frequency responses up to 15 kHz, and with impulsive type noise.

In view of the agreement on the weighting curve and as most types of noise measuring instruments give results more in accordance with subjective assessment when used in conjunction with a weighting network having this characteristic, it is concluded that the use of this type of weighting network can be recommended.

Although the standard reference frequency for acoustical measurements is 1000 Hz, a question has arisen as to whether it is in fact appropriate as the reference frequency for the noise-measurement weighting curve.

Further studies therefore need to be carried out to determine both the desirable reference frequency for the weighting curve and the time response characteristics of the measuring instrument in order to give the best agreement with subjective assessment of noise.

Bibliography

1. Niese, H. Proposal for a new sound level meter. *Hochfrequenztechnik und Elektroakustik*, **66/4**, 125 (January, 1958).

* This Report was adopted unanimously.

REPORT 465 *

DETERMINATION OF THE SUBJECTIVE LOUDNESS OF A BROADCASTING PROGRAMME

(Question 4/10)

(1970)

1. Question 4/X was adopted subsequent to the Interim Meeting of Study Group X, Vienna, 1965, and Docs. X/127 (Federal Republic of Germany), X/130 (Canada), X/137 (U.S.A.) and X/154 (O.I.R.T.) were considered at the XIth Plenary Assembly, Oslo, 1966, resulting in Doc. X/198, 1963–1966.

2. During the Interim Meeting of Study Group X, Palma de Mallorca, 1968 and the Final Meeting, Geneva, 1969, the following documents were considered:

2.1 Doc. X/8 (U.S.A.) suggests as an interim solution, the use of a standard loudness reference recording with which programmes may be compared.

2.2 Doc. X/38 (U.S.A.) describes a programme loudness meter which uses a loudness contour filter and selected attack and decay times to indicate units of loudness.

2.3 Doc. X/34 (U.S.A.) describes a unit which uses also a loudness contour filter and selected attack and decay times to adjust automatically the programme level to avoid abnormal loudness variations.

2.4 Doc. X/151 (U.S.A.) describes a new programme loudness indicator which measures the contents of several frequency bands over the audio-frequency spectrum. It is designed to measure the relative loudness levels of various programme sequences. The document points to the possibility of automatic control of programme loudness.

2.5 Doc. X/7 (U.S.A.) proposed a new Study Programme to answer Question 4/10 on the subjective loudness.

3. Study Group 10 agrees that a standard reference loudness tape should be produced for the use of the Administrations taking part in this Study Programme. This tape should contain as a minimum a variety of different programme material using several different languages and will be recorded with a constant peak level.

The B.B.C. has produced a provisional loudness tape with a comprehensive range of programme material having different subjective loudness characteristics. This has been published by the C.C.I.R. Secretariat, for study purposes leading to the possible production of a C.C.I.R. standard reference loudness tape. Resolution 57 has established an Interim Working Party with this object.

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* This Report was adopted unanimously.

REPORT 466 *

TELEVISION TAPE RECORDING

Emphasis applied to the video-frequency signal

(1970)

1. Introduction

To improve the signal-to-noise ratio of the reproduced video signal, it is customary to apply to this signal an amount of pre-emphasis in recording and the corresponding amount of de-emphasis in reproduction. Two methods are currently used to define the emphasis applied, making use of:

— a reference record chain,

— a reference reproduction chain.

2. Description of a reference record chain

For reference purposes an ideal recording chain is defined, consisting of:

— a modulator having a flat frequency response with respect to the modulating video frequencies;

— a radio-frequency section having a transfer characteristic such as to produce constant amplitude alternating magnetic flux emanating from the video-head pole tips when driven by an alternating signal from the modulator having constant amplitude;

— a video pre-emphasis network inserted before the modulation stage.

The pre-emphasis is defined by the frequency and phase characteristics of a network such as that shown in Fig. 1, fed from a low-impedance source and feeding a high-impedance load, having the time constants indicated in Recommendation 469.

The ideal recording chain is intended to be taken as a basis for producing reference tapes to be used for the alignment of television tape-recorders.

In practice, when using present-day recording chains, the following points should also be considered:

— an approximately linear relationship exists between the magnetic flux emanating from the video-head pole tips and the radio-frequency current flowing through the video-head windings;

— the amplitude of the record current in the video heads should be such as to produce maximum radio-frequency output, in replay, at the frequency corresponding to mid-grey level.

3. Description of a reference reproduction chain

For reference purposes an ideal reproducing chain is defined, consisting of:

— a radio-frequency section having a flat frequency response over the passband of interest;

— a demodulator having a flat frequency response with respect to the demodulated video frequencies;

— a video de-emphasis network inserted after the demodulation stage.

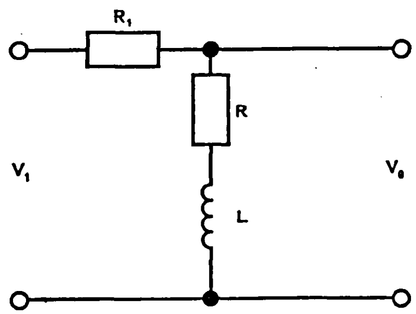
The video de-emphasis characteristic is defined as the normalized impedance of the network in Fig. 2, having the time constants indicated in Recommendation 469.

* This Report was adopted unanimously.

4. Use of a reference tape

A practical method of specifying the record and the reproduction chain is to make use of a reference tape. By this means the characteristic of the reference recording chain is completely described, so that the characteristic of any reproducing chain can be checked.

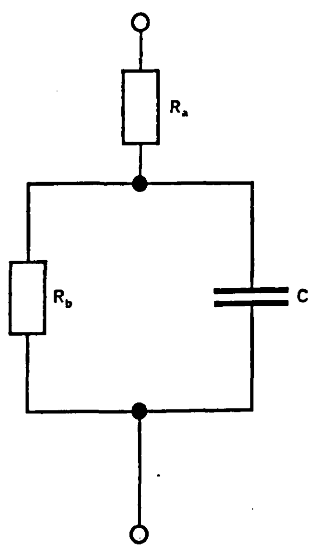
In addition once the reproducing chain has been made to conform with the reference tape, it becomes possible to check also the recording chain and to bring it into conformity with it. It therefore appears desirable that a common reference tape be made available.



$t_1 = L/(R_1 + R)$

$t_2 = L/R$

FIGURE 1



$t_1 = R_a R_b C/(R_a + R_b)$

$t_2 = R_b C$

FIGURE 2

REPORT 467 *

USE OF TAPE CARTRIDGES FOR BROADCASTING

(Study Programme 1A-1/10)

(1970)

Study Group 10 has received several contributions on the use of tape cartridges. These are Docs. X/18 and X/136 (U.S.A.), 1963–1966 and X/179 (E.B.U.), 1966–1969.

Cartridges are mainly used for the following:

— lightweight outside broadcasting equipment;
— broadcasting short sequences, such as identifications or short programme inserts;
— uninterrupted automatic broadcasting of recorded programmes.

The main characteristics of a magnetic tape cartridge are:

— type of cartridge, size, capacity;
— width of tape, position of tracks;
— speed and recording standards;
— coded data (identification, control signals, etc.).

Many types of cartridge are now available. The basic systems are those of the endless loop cartridge and of the co-planar spool-to-spool cartridge.

The endless loop cartridge is particularly well suited to short sequences. It is also being increasingly used for automatic broadcasting of medium-length recorded programmes.

The co-planar spool system would be useful for light-weight, low-cost outside broadcasting equipment, but the way in which the spools are arranged makes it necessary to re-copy the tape.

None of the systems can be applied universally. The various requirements must be listed and research pursued.

REPORT 468 *

METHODS OF SYNCHRONIZING VARIOUS RECORDING AND REPRODUCING SYSTEMS

(Questions 18-1/10 and 22/11)

(1970)

1. Several documents answer in part the question of synchronization between the various forms of sound and/or image.

These are: Docs. X/51 (Spain), 1966–1969, X/134 (U.S.A.), 1966–1969, X/163 (France), 1966–1969 and X/189 (Spain), 1966–1969.

2. **Required capability of synchronization**

There are several methods of synchronization between sound tapes, television tapes and films applicable to the various modes of operation.

It is frequently necessary to have available two or more synchronous sound tracks.

* This Report was adopted unanimously.

In some cases (synchronous copy or play-back), synchronization must be maintained in the forward direction only.

In the processes of programme production (lip synchronization or editing) synchronization must be maintained in both forward and reverse directions.

Additional capabilities of synchronization systems may prove useful although not essential, for example, maintaining synchronization in case of film breakage, automatic loading and phasing of several sources.

3. Usual methods of synchronization

Electro-mechanical methods such as sprocket-driven perforated film and tape have been in use for a long time.

More recently electronic methods of synchronization have been made available utilizing a sequence of markings (perforations, printed marks or recorded pulses) on the tapes or films to be synchronized.

These markings are generally related to the picture frame rate. Furthermore, one may identify the markings by the use of a numbering code or a form of timing information.

In normal play-back or recording operation phase comparison between markings may be used for synchronization. Electronic counting of the marks or even individual recognition of each mark could be needed for synchronization in both directions.

4. Conclusions

The different methods set forth are not mutually exclusive but are complementary and enable maximum simplicity and economy to be achieved in synchronization.

There is a large number of different systems of sound tapes in use and it is essential that a format be recommended which could be used with all existing types of picture sources (film and video tape recording) for whatever synchronization process is used.

All synchronizing processes in the future should use a synchronization signal related to 24 Hz or 25 Hz (nominal).

REPORT 469 *

PHOTOGRAPHIC FILM RECORDING OF COLOUR TELEVISION SIGNALS

(Question 20/11)

(1970)

1. Introduction

A serious limitation in the international exchange of colour television programmes has been the lack of a means for transferring the electronic video-frequency signal to motion-picture film, without significant loss in quality. Although several systems are in limited commercial use at present, all rely upon some form of optical image-transducer and, in consequence, are limited by the aperture of the optical system and noise level characteristics.

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* This Report was adopted unanimously.

Because of the limited use of the various systems, and shortcomings in the quality of recordings, it is premature to answer Question 20/11. Therefore, this Report is for information purposes only and describes practices used for photographic film recording of colour television programme material from video-frequency signals. Also noted are systems under development which use direct electron beam recording or using laser optics, which may ultimately result in significant improvement in the film recording process.

2. Present-day systems

The following is a brief description of representative film recording systems in current use and those known to be under development.

2.1 *Triniscope*

This is a three-tube picture presentation, registered optically for colour photography through a system of dichroic mirrors. Although registration is a problem, this system provides enough brightness for photography with finer grain reversal and negative-positive film systems. It has been used for several years by a few organizations.

2.2 *Shadow-mask*

More common is a single-tube presentation using conventional or special shadow-mask tubes. Signal processing is frequently done to correct for colour, sharpness or contrast errors. Conventional tubes require the higher speed, daylight-balanced 16 mm colour reversal films for adequate exposure. A special tube with a clear face-plate is used to provide just enough brightness to expose a finer-grain 16 mm colour reversal film, from which inexpensive multiple copies can be made by photographic duplication. Otherwise, multiple copies are made by repeated recordings from video tape onto the high-speed reversal colour films.

This latter method is used by broadcasters for distribution of television news programmes, and for recording where few copies are required. The method employing the special tube and finer-grain printing master is used primarily to obtain recordings of commercials and other promotional material.

Some limited use has been made of 35 mm negative colour film for this photography, from which either 35 mm or 16 mm prints can be derived.

2.3 *Sequential display*

One organization is providing a recording service in which red-, blue- and green-separation records are made, sequentially, from a colour video- tape recording. These separate records on black-and-white film are combined by photographic printing, to provide a photographic colour print or a master from which multiple copies can be made.

3. New systems

3.1 *Electron beam colour-film recording*

A system using electron beam equipment is being developed for use in making colour separation records.

3.2 *Electron video recording*

A system of recording a luminance image and a coded colour image side-by-side on black-and-white film by means of an electron beam is being developed. Playback is accomplished on 16 mm film by means of a two-channel (luminance and chrominance) telecine camera.

3.3 *Colour film recording using a laser beam*

Several organizations are investigating the use of laser beams for producing colour film recordings. Equipment is available for producing the colour television image. However, so far, a film recording system has not been demonstrated.

REPORT 470 *

MEASURING METHODS FOR TELEVISION TAPE RECORDING

(Study Programme 18C/11)

(1970)

In recent years, many studies have been conducted in various countries on the most appropriate measuring methods for television tape recordings. These studies cannot yet be considered to be concluded, and it seems appropriate to give a list of documents bearing on this problem, in order to facilitate future work.

C.C.I.R. documents relevant to Study Programme 18C/11, submitted in the period 1966–1969, are:

X/2 (E.B.U.)	Test signals to be used for the adjustments of television tape recorders.
X/45 (France)	Measurement of differential phase on video-tape recorders.
X/59 (Italy)	Recording of television signals on magnetic tape.
X/168 (France)	Relative speed errors in television tape recorders.
X/170 (O.I.R.T.)	Evaluation and measurement of the most important qualitative parameters of the video frequency part of video-tape recorders.
X/182 (E.B.U.)	Definition and measurement of drop-outs in television tape recordings.
X/201 (Italy)	Recording of television signals on magnetic tape.

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* This Report was adopted unanimously.

SECTION 10/11B: BROADCASTING SERVICE (SOUND AND TELEVISION) USING SATELLITES

RECOMMENDATIONS AND REPORTS

Recommendations

There are no Recommendations in this section.

Reports

REPORT 471 *

TERMINOLOGY RELATIVE TO THE USE OF SPACE COMMUNICATION TECHNIQUES FOR BROADCASTING

(1970)

To facilitate the work of the C.C.I.R. the following previously defined terminology is noted and provisional new terminology is proposed.

1. Broadcasting-satellite service

1.1 A space service in which signals transmitted or retransmitted by space stations, or transmitted by reflection from objects in orbit around the Earth, are intended for direct reception by the general public. **

1.2 *Broadcasting-satellite space station*

A space station in the broadcasting-satellite service, on an earth satellite.

1.3 *Methods of reception*

1.3.1 *Individual reception* (in the broadcasting-satellite service)

The reception of emissions from a broadcasting-satellite space station by simple domestic installations and in particular those possessing small antennae.

1.3.2 *Community reception* (in the broadcasting-satellite service) ***

The reception of emissions from a broadcasting-satellite space station by receiving equipment which in some cases may be a large installation and have large antennae, intended for use by a group of the general public at one location or through a distribution system covering a limited area.

1.4 *Reception quality*

1.4.1 *Primary grade of reception quality* (in the broadcasting-satellite service)

A quality of reception of emissions from a broadcasting-satellite space station which is subjectively comparable to that provided by a terrestrial broadcasting station in its main service area.****

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* This Report was adopted unanimously.

** See No. 84AP (Spa) of the Radio Regulations, 1968 edition.

*** This term needs further study, especially to define more precisely the demarcation between community reception in the broadcasting-satellite service and programme distribution in the communication-satellite service.

**** The main service area of a terrestrial broadcasting station is not defined but corresponds to a field strength somewhat higher than the minimum values of field quoted in Recommendations 448, 411-1, 412 and 417-2.

1.4.2 *Secondary grade of reception quality* (in the broadcasting-satellite service)

A quality of reception of emissions from a broadcasting-satellite space station which is subjectively inferior to the primary grade of reception quality but is still acceptable.*

1.5 *Power flux-densities*

To permit individual or community reception with either grade of reception quality, broadcasting-satellite space stations may provide a high, medium or low power flux-density at the receiving site.

1.5.1 *High power flux-density* (in the broadcasting-satellite service)

A power flux-density which enables signals radiated by broadcasting-satellite space stations to be received by simple receiving installations with a primary grade of reception quality.

1.5.2 *Medium power flux-density* (in the broadcasting-satellite service)

A power flux-density which enables signals radiated by broadcasting-satellite space stations to be received either by simple receiving installations with a secondary grade of reception quality or by more sensitive receiving arrangements with a primary grade of reception quality.

1.5.3 *Low power flux-density* (in the broadcasting-satellite service)

A power flux-density which enables signals radiated by broadcasting-satellite space stations to be received with either grade of reception quality depending on the degree of the sensitivity of the receiving arrangements.

2. Use of the communication-satellite service for the distribution of broadcasting programmes to terrestrial broadcasting stations

2.1 *Direct distribution*

Use of a communication-satellite service to relay broadcasting programmes from one or more points of origin for direct distribution to terrestrial broadcasting stations and, possibly, other signals necessary for their operation.

2.2 *Indirect distribution*

Use of a communication-satellite service to relay broadcasting programmes from one or more points of origin to various earth stations for further distribution to the terrestrial broadcasting stations and, possibly, other signals necessary for their operation.

Note 1. — The attention of the Administrations is called to the need for further studies and to collect the necessary data to establish the characteristics for quantitative definitions for the grades of reception quality referred to in § 1.4.

Note 2. — Concerns the French text only.

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* See Report 409-1.

REPORT 215-2 *

FEASIBILITY OF SOUND AND TELEVISION BROADCASTING FROM SATELLITES

(Questions 34/10 and 23/11)

(1963 – 1966 – 1970)

1. Introduction

The large coverage area possible from a satellite-borne radio transmitter raises the possibility of establishing a direct broadcasting service to the general public, despite the major technical problems that would need to be resolved. An earth-station transmitter would direct programme material to the satellite which, in turn, would broadcast this over a wide area to individual home receivers, by using an active repeater or transmitter.

Communication-satellite systems used to relay programme material to earth stations for subsequent broadcast are not considered to be a space broadcasting system and are not, therefore, discussed in this Report.

2. Factors affecting choice of orbit

2.1 Among the factors to be considered in the selection of preferred orbits for satellite broadcasting are coverage, number of daily broadcast hours desired and antenna characteristics.

The satellite orbit for a broadcast service must provide coverage of selected regions of the Earth during desired viewing or listening hours which may vary from several to twenty-four hours per day. For non-continuous broadcast periods, it is desirable to have these intervals occur at the same local time each day. Regardless of the duration of the broadcast period, it is desirable to have an orbit that does not require antenna tracking equipment at broadcast receiving installations.

2.2 A geostationary satellite (altitude about 35 870 km above the equator) would permit a continuous broadcast service to areas as small as individual countries or as large as continents, up to about one third of the surface of the Earth. The limitation imposed by the minimum usable angle of elevation can be determined from Fig. 10 of Report 205-2. A geostationary satellite also permits the use, if required, of a fixed receiving antenna of very high gain (and hence directivity).

2.3 A satellite in a sub-synchronous circular equatorial orbit can provide coverage at the same local time each day. The number of uninterrupted broadcast hours possible from such a satellite to a given area on the surface of the Earth is a function of the satellite altitude and the latitude of the receiving point. Representative visibility times are shown in Table I.

Because the sub-synchronous satellites in circular orbits have a lower altitude than a geostationary satellite, a stronger signal is available for a given transmitter e.i.r.p. Such satellites may, therefore, have an advantage when the maximum transmitting antenna gain is limited by size restrictions and when the receiving antenna can be nearly omnidirectional.

In band 8 (VHF) or at higher frequencies a satisfactory signal-to-noise ratio can be achieved using frequency modulation with a geostationary satellite or other high-altitude satellite, so that the lower altitude satellites do not appear to have any advantage.

* This Report was adopted unanimously.

2.4 A satellite with a period of 12 hours, in an elliptical orbit having a plane inclined at about 65° to the equatorial plane and an apogee of 40 000 km well North of the equator, can provide a larger area of coverage in the northern hemisphere than a geostationary satellite. The use of several satellites in such orbits can provide an uninterrupted service. The times of visibility of one satellite are given in Table II for a particular latitude (60°N) of the receiving point, and a particular minimum angle of elevation (20°). In theory, because of the non-spherical shape of the Earth, an angle of inclination of the orbit of 63·4° would ensure that the major axis does not drift in the plane of the orbit, and, therefore, that successive apogees will occur at the same terrestrial latitude.

In the example of Table II the minor axis of the orbit ellipse is assumed parallel to the equatorial plane. The maximum period of visibility from a given point on the Earth at latitude 60° (10·6 hours) is then obtained when the apogee is at the same longitude as the point.

In selecting highly elliptical orbits, it is preferable to avoid passage through the van Allen belt, or to ensure that satellites pass rapidly through the radiation region in order to avoid damage to components.

2.5 For the various orbits, uninterrupted reception is possible only when the satellite remains within the beam of the receiving antenna. Assuming the antenna is fixed, therefore, it must have a sufficiently large beamwidth to ensure the desired service.

If a sub-synchronous circular orbit is used, it would not be possible to employ most of the available period of visibility, using a fixed receiving antenna, unless the antenna is of low gain (e.g. a half-power beamwidth of 110° corresponding to a maximum gain of 6 dB).

If a sub-synchronous highly elliptical orbit is used, a fixed antenna of higher gain could be used (e.g. a half-power beamwidth of 28° corresponding to a maximum gain of 15 dB).

If a geostationary satellite is used, the antenna gain can be higher than in the examples above, but the maximum antenna gain might be limited (because of the consequent small beamwidth) either by practical considerations of the receiving installation or by the lack of stability of the position of the satellite as discussed in § 3.1.

2.6 If narrow-beam receiving antennae (beamwidth less than about 5°) are used, a significant increase in noise level can occur for periods of a few minutes when the Sun is in the antenna beam. For geostationary satellite orbits these periods occur in the daytime for a few successive days in spring and autumn.

3. Satellite aspects

This section provides estimates of spacecraft technology that could be available. Much of the material in this section has been derived from [13]. These estimates assume that programmes will be established, or continued, at a level sufficient to bring about these theoretically attainable developments.

The fraction of total spacecraft mass devoted to its several sub-systems is a function of the total spacecraft mass itself. As the mass increases, the fraction required for the " house-keeping " functions (attitude control and station keeping) and for the antenna decreases so that the fraction available for the transmitter and the power supply (and for thermal control) increases. Consequently larger satellites represent a more efficient use of the available payload of launch vehicles.

3.1 *Station keeping*

The slight inequalities in the gravitational field of the Earth, together with the gravitational forces due to the Sun and Moon have perturbing effects on satellites which otherwise would remain stationary, but these can be counteracted by orbit correction or " station-keeping " techniques.

A geostationary satellite will experience extremely slight eastward or westward forces which change the longitudinal drift of the satellite.

Other perturbing forces tend to change the inclination of the orbit plane at approximately 0·8° per year, thereby causing the satellite to undergo corresponding daily variations in latitude.

Present station-keeping techniques develop corrective thrust to overcome the gravitational forces by the use of small propulsion jets on the satellite, operated by propellents stored on board. The extent to which correction is required depends upon the allowable displacement of the satellite.

East-West (longitudinal) station-keeping is usually essential, because the uncorrected drift may be relatively large and rapid. Fortunately, the required rate of propellent consumption is very low. North-South (latitudinal) station-keeping, to keep the orbit close to the plane of the equator, will become more important as satellites achieve longer life. Latitude station-keeping requires approximately ten times the amount of propellent as does longitude station-keeping.

For frequencies up to 1 GHz where the required beamwidth of the receiving antenna is not expected to be less than 5°, a station-keeping accuracy of 1° will be sufficient to ensure that the satellite remains in the beam of receiving antennae. Above 1 GHz, accuracies of the order of 0·25° may be required. The longitudinal drift for satellites currently in a geostationary orbit can be held to 0·1° during a satellite lifetime of at least five years. Satellites now under construction will be capable of controlling the daily variation in latitude to the same accuracy. Station-keeping techniques for achieving the orbital accuracy required for a geostationary broadcasting satellite, therefore, are technically feasible.

3.2 *Primary power and other factors associated with the space environment*

3.2.1 *Solar arrays*

As the projected power requirements have increased, attention has been directed to the use of light-weight sun-oriented arrays. Most of the interest is centred around photo-voltaic cells mounted on a flexible substrate which is rolled on a drum for packaging [30]. These arrays are deployed by means of extendable booms.

A 1·5 kW version of a roll-out array is technically feasible now. Flight data should confirm present estimates that a reliable 12 kW (decreasing to 10 kW at the end of five years) roll-out array could be designed.

The mass of a broadcast satellite as a function of solar array power including necessary power conditioning equipment can be approximated by the following formula, which is independent of operating frequency.

$$W\,(\text{kg}) \approx 250 + 110\,P$$

where P is the solar-array power (kW).

A solar array does not provide power during passage in the shadow of the Earth. With a geostationary satellite there is one eclipse each day, but only within the periods of approximately 1 March to 11 April and 1 September to 11 October. Near the centre of these periods, the eclipse lasts about 70 minutes about midnight at the satellite longitude; the duration is less towards the beginning and end of the periods. In the case of longer eclipses, sufficient warm-up time must be allowed after the end of the eclipse. In the past, about one-half hour has been required.

The practical consequences can be minimized by shifting the service break to late in the night, which can be done by placing the satellite to the west of its service area; batteries can also be placed on board but this would greatly increase the weight of the satellite.

3.2.2 *Other power sources*

Nuclear reactors and fuel cells are possible sources of primary power, but additional development will be required before they will be competitive with solar arrays in terms of cost, mass and reliability.

Thermoelectric junctions and thermionic cells may also be considered as a means of converting heat from the Sun or from isotope sources into electrical energy, and offer the possibility of less total mass in the power unit for a given electrical output. Work is in progress on the development of such devices and their application to spacecraft [28].

3.3 *Radio-frequency power*

3.3.1 The final stage of the broadcast transmitter is the major consumer of power on the satellite. Solid-state transmitter modules for a frequency of about 800 MHz and at power levels of about 100 W will be available in the near future. Appreciably higher powers, particularly at higher frequencies, will require vacuum tubes. Powers of the order of a few kilowatts could be provided by gridded tubes up to 2 GHz, or by crossed field amplifiers up to 5 GHz. For the frequency range 2 to 20 GHz travelling-wave tubes or klystrons might provide powers in the range 1 to 7·5 kW, depending on the frequency. An efficiency of 35 to 65%, including any loss in power conditioning units, can be achieved with these systems. Both efficiency and power output decrease with increasing frequency.

3.3.2 *Summary of radio-frequency power limits*

A graphical summary of some of the factors that limit radio-frequency power is shown in Fig. 1*a*. Total output power is limited by solar array power and transmitter efficiency. The output power of a single tube is limited by cathode loading and beam compression. The power in a waveguide component is limited by radio-frequency breakdown and heating.

3.3.3 *Equivalent isotropically radiated power*

Combining the factors shown in Fig. 1*a* with gain limitations discussed in § 3.4, an estimate of maximum e.i.r.p. that will be technically feasible can be derived as a function of frequency (Fig. 1*b*). A 12 m antenna having been assumed, the zone of coverage obviously will decrease with increasing frequency.

For a given zone of coverage, say 2°, we can look forward to maximum values of e.i.r.p. of 76 dBW at 800 MHz and perhaps 70 dBW at 12 GHz with still higher powers technically feasible at a later date.

The comment at the beginning of § 3, concerning the necessity for adequate development programmes is particularly relevant to the estimates just given.

Experience indicates that perhaps five years would be necessary to carry out such programmes.

3.3.4 *Thermal control*

The major problems are associated with heat rejection from the power conditioning components and from the high-power stages of the transmitter. Solid-state components lend themselves to simple passive methods of control. However, the low operating temperatures (350°K to 390°K) require a significant amount of radiator area. Other devices, such as gridded tubes and microwave tubes, have high heat dissipation densities and high temperatures. The higher operating temperatures (470°K to 500°K) minimize the radiator area requirements.

The development of heat pipes provides a promising method of heat transfer from the source to the radiator. Heat pipes have been used for thermal control on spacecraft [31] and in heat rejection from high power tubes on the ground.

Direct radiation from a beam collector to space is being investigated with a klystron to be used in deep-space communications applications [32].

3.4 *Gain and stability of the satellite antenna*

Broadcast satellite transmitting antennae can be divided into two categories: small antennae which can be launched in operating position; and large antennae which due to shroud limitations must be folded for launch and then deployed in space. An antenna diameter of approximately 3 metres divides the two classes. A variety of small antennae have been used in space and pose no major technological problems for the broadcast satellite.

3.4.1 It is considered theoretically possible to erect in space, antennae with large overall dimensions, e.g., 30 m diameter parabolic antennae [33]. This could give, for example, a gain (relative to an isotropic radiator) of about 27 dB at 100 MHz with a beamwidth of 7° or 45 dB at 800 MHz with a beamwidth of 1°.

The problems of packaging, deployment and structural stability of the large antenna are increased when the antenna is used in conjunction with a large solar array. It is expected that erectable antennae 12 m in diameter will be technically feasible for use with such large solar arrays.

If much higher frequencies are used, the transmitting antennae will be much smaller; for example, a beamwidth of 1° at 12 GHz required an antenna diameter of only about 2 m and this is a major advantage of the higher frequencies.

3.4.2 The transmitting antenna of a broadcasting satellite must be pointed with a suitable degree of accuracy to maintain coverage of a specific area on the surface of the Earth.

The angular accuracy required to maintain intended coverage is a function of the beamwidth of the transmitting antenna. Narrow-beam antennae require greater pointing accuracy than broad-beam antennae. A pointing accuracy of the order of one-tenth of antenna beamwidth would appear to be a reasonable design goal.

Using current techniques of attitude control for spacecraft and antenna beam pointing, it is feasible to direct and hold an antenna beam to an accuracy of 0·05° (in pitch, roll and yaw). This accuracy would be sufficient to meet the one-tenth beamwidth requirement of the narrowest beamwidth contemplated for a transmitting antenna of a broadcasting satellit

3.4.3 Other important factors in designing antennae for broadcasting satellites include " beam-shaping " and minimization of side-lobes.

3.5 *Life*

Current planning of systems assumes a mean satellite life of about seven years. Studies and the performance of satellite systems so far encourage the view that a life expectancy of up to ten years can be achieved by careful design and provision of certain reserve equipments. In particular, the solar panels must be large enough to allow for the progressive deterioration that takes place in space. Fuel requirements for station-keeping and attitude stabilization may well be large, possibly of the order of 20 to 25% of the mass of the satellite if existing techniques are employed. It is hoped that future developments could reduce this proportion to less than about 10%.

4. Receiving equipment

A wide range of receiving equipment characteristics may be considered. These characteristics affect the size, mass and complexity of the satellite required to provide a given quality of service because receiver sensitivity can be traded for satellite power. The characteristics are also influenced by the standards chosen, some of which are referred to in § 5.2. [14] and Report 473 contain information regarding receiving systems for the broadcasting-satellite service.

5. Other technical factors

In addition to satellite and receiving technology, other factors must be considered in evaluating the feasibility of broadcasting-satellite systems. Some of these factors are discussed below, but frequency sharing between the broadcasting-satellite service and terrestrial services, which is an important factor, is not discussed below, since it forms the subject of separate Reports (see Report 474 and Report 475).

5.1 *Reception quality*

Subjective quality of reception is influenced by the signal-to-noise ratio as measured at a specific point in the system.

Numerous methods for evaluating subjective picture quality are summarized in Report 313-2. The required carrier-to-noise ratio will be determined not only by the required quality but also by the nature of the system under consideration.

5.2 *Influence of standards in the case of television*

Three categories of standards may be designated as follows: picture standards, transmitting standards, and channel standards. The picture standard describes the scan process, line structure, etc., as set forth in Report 308-2. The transmitting standard describes the RF radiated signal, i.e., modulation mode, spacing between sound carriers, etc. It is also set forth in Report 308-2. The channel standard gives the radio frequency and assigned bandwidth.

To provide television broadcasting-satellite service, three approaches may be considered:

- exactly match the existing standards as employed for terrestrial broadcasting in the geographic area of interest;
- provide a receiving device to convert the satellite signal to one usable by a standard receiver;
- provide a receiver designed specifically for broadcasting-satellite service.

5.3 *Coverage*

The earth area covered by a satellite antenna is a function of the antenna beamwidth. Antenna beamwidth depends upon frequency and the aperture of the antenna. Fig. 2*c* shows these relationships for a range of parameters. Coverage diameter is given for the antenna beam centred on the sub-satellite point and would be larger in other cases.

5.4 *Propagation*

A general discussion is given in Report 205-2 of the propagation characteristics at different frequencies. A more detailed discussion is given in Report 234-2. Atmospheric factors are not very important in bands 8 and 9; in band 10 they have an increasingly unfavourable effect as the frequency increases. Special factors may need to be considered in specific situations. For example, according to [34] extremely heavy rainfall such as that encountered in monsoon regions may degrade the quality of reception at those times or would require larger margins for atmospheric attenuation, or else make the use of frequencies in the upper part of band 9 or the lower part of band 10 preferable.

5.5 *The broadcasting of several programmes*

Although this Report does not deal with frequency usage some comment might be made on this question in relation to satellite requirements. For reasons of operation and cost, the individual receiving equipment should be able to obtain satisfactory results with a fixed-direction aerial not exceeding about 1 metre in diameter. Nevertheless, it may be desirable that this equipment be capable of providing the user with a choice of several programmes; this would require the use of several transmission channels radiated by transmitters either on closely spaced satellites or possibly on a single, larger satellite.

However, to limit the width of the frequency spectrum to be allotted to the system, it would be of advantage if the same channels could be re-used for transmissions to different service areas, beamed from sufficiently separated points on the geostationary orbit. All things being equal, the higher frequencies have the advantage that less angular separation is required for co-channel satellites. But there are disadvantages in having very high-directivity receiving antenna, namely stricter tolerances on their initial pointing, long-term reliability in the face of wind or movement of the supporting structure and the need for a satellite with good station-keeping accuracy.

The requirements discussed in this section are related to those for efficient use of the orbit as considered in § 5.6.

5.6 *Orbit utilization*

Since general orbit utilization principles are still being studied, the following views are preliminary and subject to revision. Nonetheless, it appears evident that the ability of several satellites at separate orbital locations to broadcast different programmes usefully at the same frequencies will be very dependent upon the directivity of the antennae on the satellites, and especially upon that of the earth receivers. Thus, at the lower frequencies now used for broadcasting, the use of the same frequencies by more than two or three such geostationary satellites appears difficult and improbable. Such difficulties diminish at higher frequencies.

Finding the most appropriate use of the geostationary satellite orbit for broadcasting entails the study of many problems, and in particular, how the same frequency can be used for broadcasting different programmes from the same satellite and from different satellites.

These problems have been examined in preliminary theoretical studies [9, 10] which have not taken into account the protection that may be given by using cross polarizations. Optimal utilization of geostationary satellite orbits also depends on the type of modulation used; the most appropriate type of modulation for this purpose has not yet been determined. Attention has been paid principally to examples of television systems operating at about 12 GHz using frequency modulation with a channel width of about 30 MHz, and using narrow-beam receiving antennae carefully aligned. These studies showed that orbital spacings of geostationary satellites providing two or more programmes to areas at a suitable spacing on the Earth (or possibly to the same area) on the same frequency channel would have to be 3° to 10°. The possibility was also envisaged of re-using the same channel at the same orbital position when the areas served are sufficiently far apart on the Earth.

In one study of a multiple-satellite system it was assumed that coverage over a large area would be provided by a continuous sequence of adjacent zones, each corresponding to a satellite antenna beamwidth of about 1°, with a different television programme (if desired) in each zone. This preliminary study suggests that, for each choice of programme receivable at a given point, a range of frequency spectrum of the order of 100 MHz would be required (Table III of [9]).

These conclusions are based on limited examples, and it is important that further studies should be undertaken by the C.C.I.R. on the frequency usage by satellite broadcasting. The replies to Question 5-1/11 and Study Programme 5-1E/11 and also replies to Study Programme 2-1J/4 on related communication-satellite problems, may facilitate these studies.

6. Television system considerations

Figs. 2*a*, 2*b* and 2*c* show the relationships between significant system parameters over a wide range and may be used to determine specific factors related to a proposed approach to system design. The dashed lines indicate one approach to show how the graphs are used.

The lower part of Fig. 2*a* shows the relation between carrier-to-noise ratio (C/N) and post-detection signal-to-noise ratio (S/N) for vestigial-sideband amplitude-modulation transmission and for a range of bandwidths for frequency-modulation transmission. * Type *M* (United States of America, Canada) picture standards were assumed. The upper part of the figure converts C/N to carrier-to-noise-temperature ratio (C/T).

The dashed lines in Fig. 2*a* show that for a value of S/N equal to 34 dB and of C/N equal to 10 dB (corresponding to the threshold of a normal frequency-modulation detector), the bandwidth of the system is determined by the intersection of the horizontal S/N line with the vertical C/N line. (The short diagonal line indicates that the radio-frequency bandwidth is approximately 17 MHz in this example.) The vertical line corresponding to a C/N value of 10 dB intersects a second diagonal line corresponding to the previously determined radio-frequency bandwidth and moving horizontally to the left-hand edge of the diagram, the value of C/T (−146 dBW/1°K for the example shown) is read.

The upper half of Fig. 2*b* converts C/T to received carrier power, *C*, and the lower half illustrates the relation between receiving antenna aperture, satellite e.i.r.p., ground field strength, and received carrier power. The C/T scale corresponds to that on Fig. 2*a*. Note that frequency is not a factor on these graphs.

The dashed lines in Fig. 2*b* indicate that for a C/T ratio of −146 dBW/1°K and a noise temperature of 2600°K (corresponding to a noise figure of 10 dB), the receiver carrier power required is −111 dBW. A diagonal line representing this receiver carrier power intersects a vertical line corresponding to the diameter of the earth-station antenna (assumed efficiency 55%). A horizontal line through this intersection determines the required satellite e.i.r.p. The scale at the extreme right indicates the corresponding field strength.

Fig. 2*c* pertains to spacecraft parameters; the lower half converts transmitter output power and antenna gain to e.i.r.p. and ground flux density. Also shown are the antenna beam-width and half-power coverage diameter as a function of antenna gain. The e.i.r.p. scales on Figs. 2*b* and 2*c* are matched to facilitate their joint use; it is at this interface that a system margin may be inserted in accordance with data presented in Report 205-2. No margin was used in the example indicated by the dashed lines. The upper half of the figure shows satellite antenna gain as a function of diameter for various frequencies.

In Fig. 2*c* a horizontal line is extended from the flux density at the sub-satellite point (−111 dBW/m^2) until it intersects a vertical line extending upward from the available satellite

* See Annex II for the derivation of the relationship between S/N and C/N for frequency modulation.

transmitter output; this intersection will determine the required satellite antenna gain (33 dB). The antenna gain lines intersect the right-hand scale at points corresponding to the half-power beamwidth of the antenna (about 4°); the scale at the extreme right indicates the diameter of the antenna beam on the Earth at the sub-satellite point. The vertical line from the horizontal antenna-gain axis (centre of diagram) intersects the appropriate diagonal frequency line. This determines the diameter of the satellite antenna.

7. System examples

Annex I gives specific examples of representative systems in tabular form. These examples derive required field strength for certain stated receiver characteristics. Other assumptions can be made, as in [8], which deals with colour television systems, which will result in different required field strengths, and different requirements for satellite e.i.r.p. The intent of all of these examples is to establish a reasonable range of satellite power output requirements for a broadcasting-satellite service

8. Administrations are urged to conduct additional studies responsive to Questions 34/10 and 23/11, in view of continuing changes in technology which will influence the feasibility of television broadcasting from satellites.

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TABLE I

Visibility times for satellites in stationary and sub-synchronous circular equatorial (non-retrograde) orbits

Approximate period (h)	Altitude (km)	Passes per day over a given point	Approximate periods of visibility above the horizon per pass (h)			
			At equator	At ± 15° lat.	At ± 30° lat.	At ± 45° lat.
24	35 870	Stationary	Continuous	Continuous	Continuous	Continuous
12	20 240	1	10·1	10·0	9·9	9·3
8	13 940	2	4·8	4·7	4·6	4·2
6	10 390	3	3·0	2·9	2·8	2·5
3	4 190	7	1·0	1·0	0·9	0·6

TABLE II

Visibility times of a satellite in a typical elliptical orbit inclined at about 65°

Approximate period (h)	Approximate apogee (km)	Approximate perigee (km)	Approximate periods of visibility per pass (h) over a reception point at 60° latitude, with an angle of elevation of the receiving antenna greater than 20°	
			Maximum	Minimum
12	40 000	500	10·6	4·5

ANNEX I

EXAMPLES OF BROADCASTING-SATELLITE SYSTEMS

1. Introduction

The Tables in this Annex give, purely as illustrative examples *, the parameters of broadcasting-satellite systems, using a geostationary satellite, that might be possible in the future. It will be observed that some of the examples call for transmitter powers greater than those likely to be practicable for many years. However, the parameters of these examples might be modified to correspond to other possibilities which demand less satellite power.

The way in which the values given in the Tables for the transmitter power in the satellite will be modified, if adjustment is made to any of the assumed parameters, is summarized below:

— assuming the use of a transmitting antenna beam of circular cross section, halving the East-West dimension of the service zone will permit a reduction of power by 6 dB. Doubling the zone dimensions will require 6 dB more power. The first change requires a narrower beamwidth and consequently twice the antenna aperture (linear dimension); in the second case the antenna aperture will be reduced by one half;

— an increase in the signal-to-noise ratio, made in order to achieve better quality, will require a corresponding increase (in decibels) in the transmitter power. Similarly a decrease will permit an equivalent decrease in the power but, with frequency modulation the deviation and radio-frequency bandwidth have to be lowered if the region of the threshold of the discriminator is approached;

— an increase in the receiving antenna gain will lead to a reduction (by an equal amount in decibels) of the transmitter power required and vice versa;

— a change in the receiving system noise factor (expressed in decibels) will change the transmitter power reouired in the same sense and by approximately the same amount (in decibels).

Thus the examples, modified as desired, can indicate the requirements to enable the public, with individual equipment to receive broadcast programmes whose technical quality would be comparable at all times with that of the services provided in the conventional way by a network of terrestrial transmitters.

2. Television broadcasting

The transmitter powers given in Table III refer to the peak power of the vision transmitter in the case of amplitude-modulation systems. With these systems, the provision of one or more sound channels associated with the television transmission will require one or more additional carriers, and no allowance has been made for the extra radio-frequency power. For the frequency-modulation system the radio-frequency power is constant. Since this system would represent a new broadcasting standard, it may not be necessary to use a separate carrier for sound.

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* Attention is drawn to the fact that different assumptions are made in the various examples, particularly regarding the reception quality, the receiving installation (noise factor, antenna size) and the area served as determined by the transmitting antenna beamwidth. Caution must be exercised when comparing the transmitter powers etc. indicated in the Tables. For example in Table IV dealing with community reception of television, a very elaborate receiving system is assumed, while in Tables V and VI a simple antenna is assumed for frequency-modulation sound reception at 100 MHz.

TABLE III

Examples of television system parameters for individual reception

	(a)	(b)	(c)	(d)	(e)	(f)
1. System						
Frequency of carrier, (MHz)	800	800	800	2500	12 000	12 000
Type of modulation	AM (1)	AM (1)	FM (2)	FM (2)	AM (1)	FM (2)
Approximate equivalent rectangular bandwidth (MHz)	6	4	15	15	6	20
Carrier-to-noise ratio before demodulation (exceeded for 99% of the time), (3) (dB)	44	30	14	14	44	17
Number of lines in system	625	525	525	525	625	625
Corresponding luminance signal-to-weighted noise ratio (4) (dB)	45	29	36	36	45	45
2. Receiving installation						
Noise power in radio-frequency bandwidth for a noise factor of 6 dB (5) (dBW)	−130	−132	−126	−126	−130	−125
Carrier power required (dBW)	− 86	−102	−112	−112	− 86	−108
Receiving antenna gain, relative to an isotropic source (6) (10) (dB)	17	17	17	29	39	39
Miscellaneous losses (7) (dB)	1	1	1	1	1	1
Effective area of antenna relative to 1 m^2 (dB)	− 3	− 3	− 3	− 1	− 5	− 5
Required flux (99% time) (dBW/m^2)	− 83	− 99	−109	−111	− 81	−103
Equivalent field strength (dB rel. 1 µV/m)	63 (1·4 mV/m)	47 (220 µV/m)	37 (70 µV/m)	35 (56 µV/m)	65 (1·8 mV/m)	43 (140 µV/m)
Free-space attenuation between isotropic sources 39 000 km apart (8) (dB)	182	182	182	192	206	206
Total atmospheric attenuation exceeded for less than 1% of time (8) (dB)	1	1	1	1	4	4
Required e.i.r.p. from satellite (dBW)	81	65	55	53	86	64

TABLE III (continued)

	(a)	(b)	(c)	(d)	(e)	(f)
3. Satellite transmitter						
Antenna beamwidth at −3 dB points (9) (degrees)	1·4	1·4	1·4	1·4	1·4	1·4
Antenna gain at edge of zone, relative to an isotropic source (10) (dB)	38	38	38	38	38	38
Approximate diameter of antenna (m)	20	20	20	6·25	1·3	1·3
Loss in feeders, filters, joints, etc. (dB)	1	1	1	1	1	1
Satellite transmitter power (dBW)	44 (25 kW)	28 (0·63 kW)	18 (63 W)	16 (40 W)	49 (80 kW)	27 (0·5 kW)

Notes relating to Table III

(1) Vestigial-sideband amplitude-modulation, negative modulation, as used for terrestrial broadcasting.

(2) In the frequency-modulation examples only a small improvement in signal-to-noise ratio resulting from the use of pre-emphasis is assumed, namely 0·6 dB.

(3) For amplitude-modulation television, the carrier value considered is the r.m.s. carrier at the peak of the modulation envelope for the vision signal. For frequency-modulation television, the carrier value considered is the unmodulated r.m.s. carrier. In example (e) the satellite transmitter power would be 2 kW for a carrier-to-noise ratio of 30 dB and a bandwidth of 4 MHz if the other assumed parameters remain the same. In an amplitude-modulation system the carrier-to-noise ratio of 44 dB corresponds to a quality of the same order as that at the limit of the primary service area of conventional broadcast transmitters in many countries.

(4) These values will normally be degraded slightly (typically 0·5 dB) by the noise contribution of the Earth-to-satellite path. The values are derived assuming weighting according to Recommendation 421-2, Annex III, for television System *M* (United States of America and Canada) in examples (b), (c) and (d) and for television Systems *D*, *K* and *L* in examples (a), (e) and (f). For Systems *D*, *I*, *K* and *L*, the luminance signal-to-unweighted noise ratio is about 8 dB (7 dB for System *M*) lower than the carrier-to-noise ratio for amplitude modulation. The parameters of frequency modulation in example (f) have been chosen to give the same luminance signal-to-weighted noise ratio as in examples (a) and (e).

(5) A pre-amplifier or frequency-changer near the antenna is assumed.

(6) At 800 MHz the receiving antenna is assumed to be a crossed-yagi or helical array with 15 dB gain relative to a half-wave dipole. At 2·5 GHz a 1·5 m paraboloid antenna is assumed. At 12 GHz a 1 m diameter paraboloid antenna is assumed.

(7) Circularly polarized antennae are assumed at both the transmitting and receiving ends. The losses in this item include ellipticity losses due to antenna imperfections, movement of the supporting structure, etc., and perturbations of the satellite position. The effective antenna area in Table III includes the miscellaneous losses.

(8) The free space attenuation is calculated for a satellite elevation of 30°. Atmospheric attenuation is small at 800 MHz but an appreciable margin may be required at 12 GHz because of the effect of cloud and precipitation. In the Table, 4 dB has been assumed at 12 GHz.

(9) The zone of service has been taken to correspond to the −3 dB points of the transmitting antenna beam, neglecting losses that might arise from pointing errors of the satellite antenna on the one hand and any advantages that might be gained by special shaping of the beam on the other hand. This example of beamwidth would cover a zone 1000 km across in an East-West direction, and 1000 km or more across (depending on the geographical latitude) in the North-South direction.

(10) Antenna efficiency of 55% assumed.

Table IV gives examples of system parameters for television broadcasting for community reception, based on receivers of improved design with a noise temperature of 750°K and antennae which are as large as possible to permit reasonably small satellite spacings. As a consequence they are larger than what would be optimum for the individual receiver. All other parameters were chosen as a compromise between moderate satellite transmitter powers and efficient spectrum and orbital utilization.

TABLE IV

Examples of television system parameters for community reception

	(g_1), (g_2)	(h)
1. System		
Frequency of carrier (MHz)	800/2500	12 000
Type of modulation	FM	FM
Approximate equivalent rectangular bandwidth (MHz)	22	18
Carrier-to-noise ratio before demodulation (exceeded for 99% of the time) (dB)	15	19
Number of lines in system	525	525
Corresponding luminance signal-to-weighted noise ratio (1) (dB)	45	45
2. Receiving installation		
Noise power in radio-frequency bandwidth for a noise factor of 4 dB (dBW)	−126	−127
Carrier power required (dBW)	−111	−108
Receiving antenna gain, relative to an isotropic source (dB)	26/36	44
Miscellaneous losses (dB)	1	1
Effective area of antenna relative to 1 m² (2), (4) (dB)	6	0
Required flux (99% time) (dBW/m²)	−117	−108
Equivalent field strength (dB rel. 1 μV/m)	29 (28 μV/m)	38 (80 μV/m)
Free-space attenuation between isotropic sources 39 000 km apart (dB)	182–192	206
Total atmospheric attenuation exceeded for less than 1% of time (3) (dB)	1	4
Required e.i.r.p. from satellite (dBW)	47	59
3. Satellite transmitter		
Antenna beamwidth at −3 dB points (degrees)	4	1
Antenna gain at edge of zone relative to an isotropic source (dB)	29	41
Approximate diameter of antenna (4) (m)	7–2·2	1·7
Loss in feeders, filters, joints, etc. (dB)	1	1
Satellite transmitter power (dBW)	19 (80 W)	19 (80 W)

Notes relating to Table IV

(1) The values are derived assuming weighting according to Recommendation 421-2, Annex III, for television System *M* (United States of America and Canada). Only a small improvement (0·6 dB) resulting from the use of pre-emphasis has been assumed.

(2) At 800 and 2500 MHz, the receiving antenna is assumed to be a 3 m paraboloid as being the maximum practicable. At 12 GHz, a 1·7 m paraboloid was assumed and this choice was to some extent dictated by beam pointing considerations and satellite positional errors.

(3) An attenuation of 4 dB is assumed at 12 GHz but this value may vary for different climatological conditions.

(4) Antenna efficiency of 55% is assumed, and the miscellaneous losses are included in the effective area of the receiving antenna.

3. Sound broadcasting

The examples which follow are representative of systems that might be considered for sound broadcasting from satellites. The assumptions adopted are consistent with current knowledge of possible requirements for these bands and should not vary materially for frequencies within about ± 30% of the specified value.

Table V lists illustrative examples of high signal-to-noise systems. It is assumed that a frequency-modulation system providing a stereophonic service is required for all bands except band 7 (HF). The basis for certain critical assumptions is given in footnotes to the Table. A monophonic service of equivalent quality would require about 20 dB lower signal level.

TABLE V

Examples of system parameters for sound broadcasting

	Monophonic broadcasting	Stereophonic broadcasting			
	(j)	(k)	(l)	(m)	(n)
1. System					
Frequency of carrier (MHz)	25	100	800	2000	12 000 (1)
Type of modulation	AM	FM (2)	FM (2)	FM (2)	FM (2)
Audio-frequency bandwidth (kHz)	10	15	15	15	15
Radio-frequency bandwidth required (kHz)	20	180	180	180	180
Carrier-to-noise ratio before demodulation (exceeded 99% time) (dB)	40	56	56	56	56
Corresponding audio-frequency signal-to-noise ratio (dB unweighted)	40	67	67	67	67
2. Receiving installation					
System noise factor in urban or tropical areas (night-time) (3) (dB)	32	18	10	8	8
Noise power in radio-frequency bandwidth (dBW)	−129	−134	−142	−144	−144
Carrier power required (dBW)	− 89	− 78	− 86	− 88	− 88
Receiving antenna gain relative to an isotropic source (dB) (4)	4	2	6	16	39
Miscellaneous losses (5) (dB)	3	1	1	1	1
Effective area of antenna, relative to 1 m² (dB)	12	0	− 14	− 12	− 5
Required flux (99% time) (dBW/m²)	−101	− 78	− 72	− 76	− 83
Equivalent field strength (dB rel. 1 μV/m)	45 (180 μV/m)	68 (2·5 mV/m)	74 (5 mV/m)	70 (3·2 mV/m)	63 (1·4 mV/m)

TABLE V (continued)

	Monophonic broadcasting	Stereophonic broadcasting			
	(j)	(k)	(l)	(m)	(n)
2. Receiving installation (continued)					
Free-space attenuation between isotropic sources 39 000 km apart (dB)	152	164	182	190	206
Total atmospheric attenuation exceeded 1% of time (dB)	3	1	1	1	4 (6)
Required e.i.r.p. from satellite (dBW)	65	86	92	88	84
3. Satellite transmitter					
Antenna beamwidth at −3 dB points (degrees)	> 20	10	1·4	1·4	1·4
Antenna gain at edge of zone relative to isotropic source (7) (dB)	12	22	38	38	38
Approximate antenna diameter (m)	(8)	24	20	8	1·3
Loss in feeders, filters, joints, etc. (dB)	0	0	1	1	1
Satellite transmitter power (dBW)	53 (200 kW)	64 (2·5 MW)	55 (316 kW)	51 (125 kW)	47 (50 kW)

Notes relating to Table V

(1) This example would probably not be valid for sound broadcasting alone unless the receiving antenna and pre-amplifier/frequency changer were common to a television system because the use of a high-gain antenna (1 m diameter paraboloid) is assumed.

(2) ± 75 kHz deviation, 50 μs pre-emphasis time constant as for terrestrial broadcasting, European area.

(3) The noise levels in urban areas (Table V) and rural or urban areas (Table VI) were derived from [4]. To ensure reception at all times of day and season and all phases of the sunspot cycle in tropical areas, at 25 MHz some 10 dB greater field strength is required.

(4) At 800 MHz, the receiving antenna is assumed to be a crossed-yagi or helix with 6 dB gain relative to isotropic. At 2000 MHz, a crossed-yagi or helix with a gain of 16 dB is assumed. At 12 GHz, a paraboloid 1 m in diameter is assumed.

(5) Circularly polarised antennae, with gains as given in the Tables, are assumed at both the transmitting and receiving ends. The losses in this item include ellipticity losses due to antenna imperfections, changes in antenna orientation through wind, movement of supporting structure etc. and perturbations of the satellite position. However, at 25 MHz, a linear receiving antenna is assumed. For this antenna the gain includes directivity obtained from ground reflection. In all cases the effective area given includes miscellaneous losses.

(6) In low latitude areas where monsoons are a major phenomenon, the attenuation due to rainfall may exceed 4 dB.

(7) Antenna efficiency of 55% assumed. In the case of 25 MHz, the gain given may be taken as 1 dB below the maximum gain, since the beamwidth is considerably greater than that required to illuminate the Earth.

(8) Dimensions are determined by the type of antenna chosen.

Table VI lists illustrative examples of lower signal-to-noise systems. Again the basis for certain critical assumptions is given in the footnotes to Table V.

TABLE VI

Additional examples of system parameters, for monophonic sound broadcasting

	(p)	(q)	(r)	(s)	(t)
1. System					
Frequency of carrier (MHz)	25	100	800	2000	12 000 (1)
Type of modulation	AM	FM (2)	FM (2)	FM (2)	FM (2)
Audio-frequency bandwidth (kHz)	10	15	15	15	15
Radio-frequency bandwidth required (kHz)	20	180	180	180	180
Carrier-to-noise ratio before demodulation (exceeded 99% time) (dB)	26	18	18	18	18
Corresponding audio-frequency signal-to-noise ratio (dB) unweighted	26	50	50	50	50
2. Receiving installation					
System noise factor: urban or tropical areas (night-time) rural areas at 100 MHz and higher frequencies (3)	32	8	8	8	8
Noise power in radio-frequency bandwidth (dBW)	−129	−144	−144	−144	−144
Carrier power required (dBW)	−103	−126	−126	−126	−126
Receiving antenna gain relative to an isotropic source (4) (dB)	8	2	6	16	39
Miscellaneous losses (5) (dB)	3	1	1	1	1
Effective area of antenna, relative to 1 m^2 (dB)	16	0	− 14	− 12	− 5
Required flux (99% time) (dBW/m^2)	−119	−126	−112	−114	−121
Equivalent field strength (4) (dB rel. 1 μV/m)	27 (22 μV/m)	20 (10 μV/m)	34 (50 μV/m)	32 (40 μV/m)	25 (18 μV/m)
Free-space attenuation between isotropic sources 39 000 km apart (dB)	152	164	182	190	206
Total atmospheric attenuation exceeded 1% of the time (dB)	3	1	1	1	4 (6)
Required e.i.r.p. from satellite (dBW)	47	38	52	50	46

TABLE VI (continued)

	(p)	(q)	(r)	(s)	(t)
3. Satellite transmitter					
Antenna beamwidth at −3 dB points (degrees)	>20	10	1·4	1·4	1·4
Antenna gain at edge of zone relative to isotropic source (7) (dB)	12	22	38	38	38
Approximate antenna diameter (m)	(8)	24	20	8	1·3
Loss in feeders, filters, joints, etc. (dB)	0	0	1	1	1
Satellite transmitter power (dBW)	35 (3·2 kW)	16 (40 W)	15 (32 W)	13 (20 W)	9 (8 W)

The notes relating to Table VI are the same as those relating to Table V.

4. Summary

4.1 The figures below summarize these examples of the signal strength and the transmitter power required for satellite broadcasting at typical frequencies which may provide useful service. In the Tables, the levels of signal strength and power indicated by rows *A*, *B* and *C* are approximately aligned to the power flux-density levels defined in Report 471. It should be noted that the exact definitions are currently under study (Questions 5-1/11 and 20-1/10). It should also be noted that the Tables are based on theoretical studies and are not yet supported by experimental data: they should therefore be regarded as provisional.

TABLE VII

Examples of field strengths from sound broadcasting satellites (dB rel. 1 μV/m)

Level of signal strength	Frequency (MHz)				
	25	100	800	2000	12 000
A	(j) 45 (180 μV/m)	(k) 68 (2·5 mV/m)	(l) 74 (5 mV/m)	(m) 70 (3·2 mV/m)	(n) 63 (1·4 mV/m)
B	(1)	(1)	(1)	(1)	(1)
C	(p) 27 (22 μV/m)	(q) 20 (10 μV/m)	(r) 34 (50 μV/m)	(s) 32 (40 μV/m)	(t) 25 (18 μV/m)

(1) Not yet studied.

TABLE VIII

Examples of field strengths from television broadcasting satellites (dB rel. 1 μV/m)

Level of signal strength	Frequency (MHz)					
	800		2500		12 000	
	AM	FM	AM	FM	AM	FM
A	(a) 63 (1·4 mV/m)	(1)	(1)	(1)	(c) 65 (1·8 mV/m)	(1)
B	(h) 47 (220 μV/m)	(1)	(1)	(1)	(1)	(f) 43 (140 μV/m)
C	(1)	(c) 37 (70 μV/m) (g_1) 29 (28 μV/m)	(1)	(d) +35 (56 μV/m) (g_2) 29 (28 μV/m)	(1)	(h) 38 (80 μV/m)

(1) Not yet studied.

4.2 The following Tables present examples of satellite radiated power for coverage areas described by the specified beamwidth. The power levels *A*, *B* and *C* correspond to the equivalent levels of signal strength tabulated in Tables VII and VIII.

TABLE IX

Examples of transmitted powers for sound broadcasting satellites

Level of power	Frequency (MHz) beamwidth (degrees)				
	25 > 20	100/10	800/1·4	2000/1·4	12 000/1·4
A	(j) 200 kW	(k) 2·5 MW	(l) 316 kW	(m) 125 kW	(n) 50 kW
B	(1)	(1)	(1)	(1)	(1)
C	(p) 3·2 kW	(q) 40 W	(r) 32 W	(s) 20 W	(t) 8 W

(1) Not yet studied.

TABLE X

Examples of transmitter powers for television broadcasting satellites

Level of power	Frequency (MHz) beamwidth (degrees)								
	800 MHz			2500 MHz			12 000 MHz		
	AM/1·4°	FM/1·4°	FM/4°	AM/1·4°	FM/1·4°	FM/4°	AM/1·4°	FM/1·4°	FM/1°
A	(a) 25 kW	(1)	(1)	(1)	(1)	(1)	(e) 80 kW	(1)	(1)
B	(b) 0·63 kW	(1)	(1)	(1)	(1)	(1)	(1)	(f) 0·5 kW	(1)
C	(1)	(c) 63 kW	(g_1) 80 W	(1)	(d) 40 W	(g_2) 80 W	(1)	(1)	(h) 80 W

(1) Not yet studied.

ANNEX II

In a frequency-modulation system in which pre-emphasis is not used:

$$S/N = C/N + F_{dB} + k_w$$

where:

- S/N = ratio of peak-to-peak luminance amplitude to weighted r.m.s. noise (dB).
- C/N = pre-detection carrier-to-noise ratio in the radio-frequency bandwidth (dB).
- F = $3\,(D_{p\text{-}p}\,/\,f_v)^2.\,(b/2f_v)$ (power ratio which equals F_{dB}, when expressed in dB).
- $D_{p\text{-}p}$ = peak-to-peak deviation by video signal (including synchronizing pulses).
- f_v = highest video frequency; (e.g. 4·2 MHz for System *M*).
- b = radio-frequency bandwidth (usually taken as $D_{p\text{-}p} + 2\,f_v$).
- k_w = weighting factor for noise in frequency-modulation systems (dB); (e.g. 10·2 dB for System *M* in U.S.A. and Canada).

Note. — In a frequency-modulation system operating near the threshold the use of pre-emphasis according to Recommendation 405-1 does not appreciably improve the signal-to-weighted noise ratio measured in accordance with Recommendation 421-2, assuming that the deviation at the reference frequency is kept unchanged. Therefore, for convenience, Fig. 2*a* corresponds to operation without pre-emphasis. For systems operated well above the threshold, the improvement is estimated to be about 3 dB. However, a further improvement can probably be obtained with the use of " over-deviation "; further discussion is given in Report 212-2.

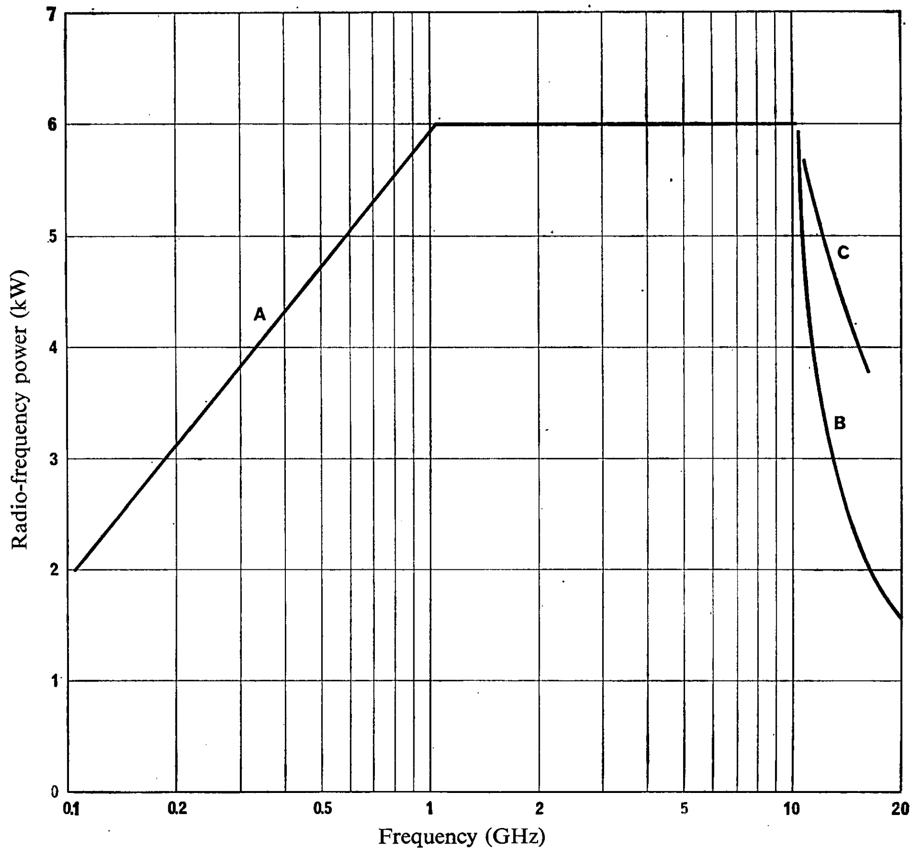

FIGURE 1*a*

Factors limiting the maximum possible radio-frequency power as a function of frequency

A: single waveguide (radio-frequency breakdown) C: single waveguide (heating)
B: single tube (cathode loading)

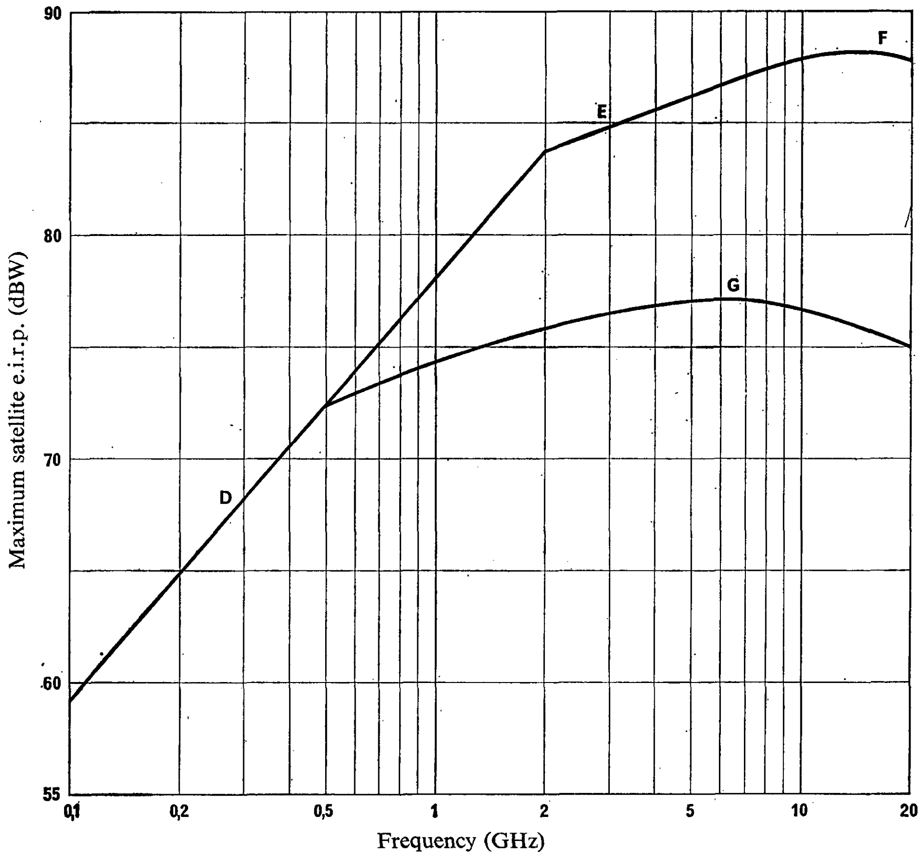

FIGURE 1*b*

Factors limiting the maximum possible e.i.r.p. as a function of frequency

D: antenna size (12 m diameter)
E: beam pointing accuracy
F: surface tolerance of reflector
G: requirement for very low side-lobes

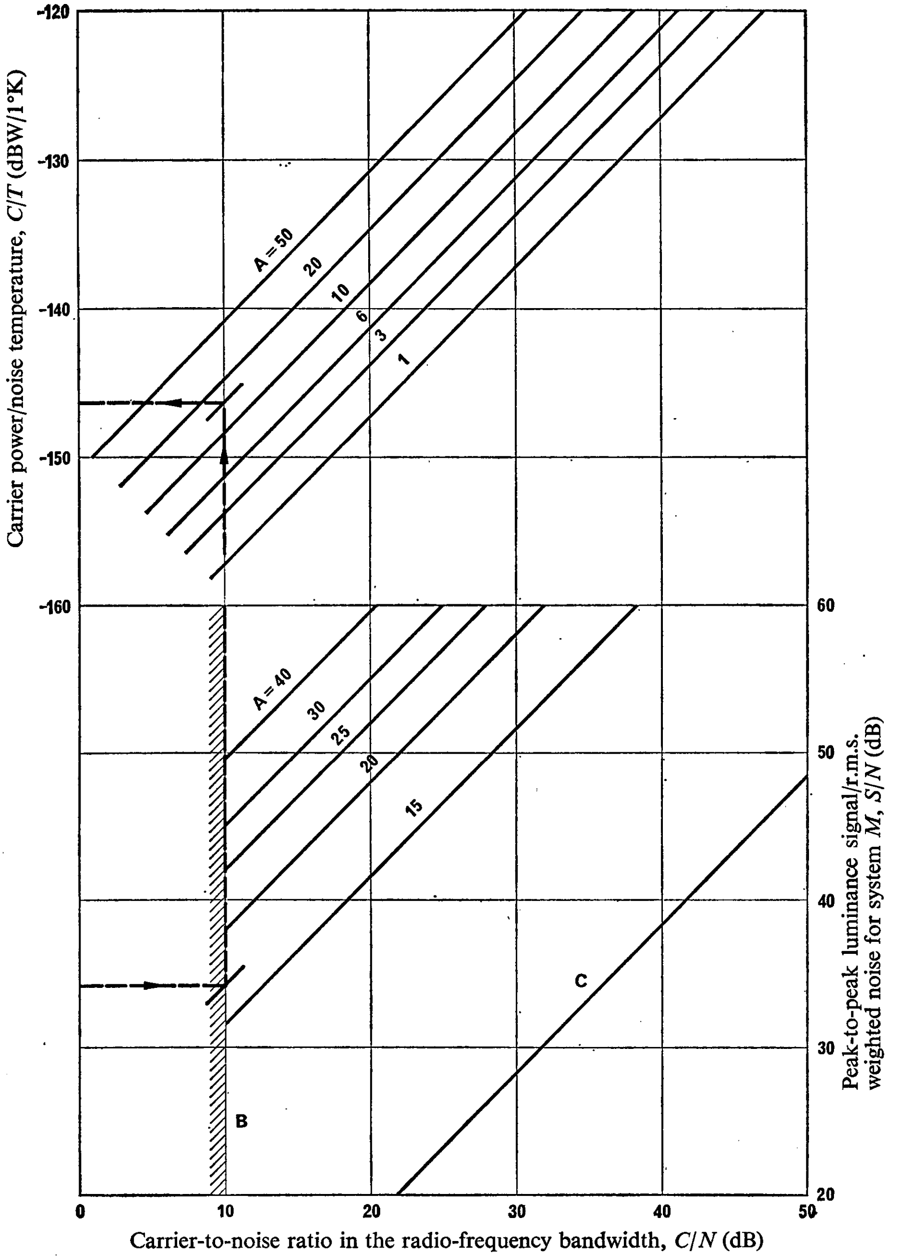

FIGURE 2*a*

A: radio-frequency bandwidth (MHz)
B: normal frequency-modulation threshold
C: vestigial-sideband amplitude-modulation

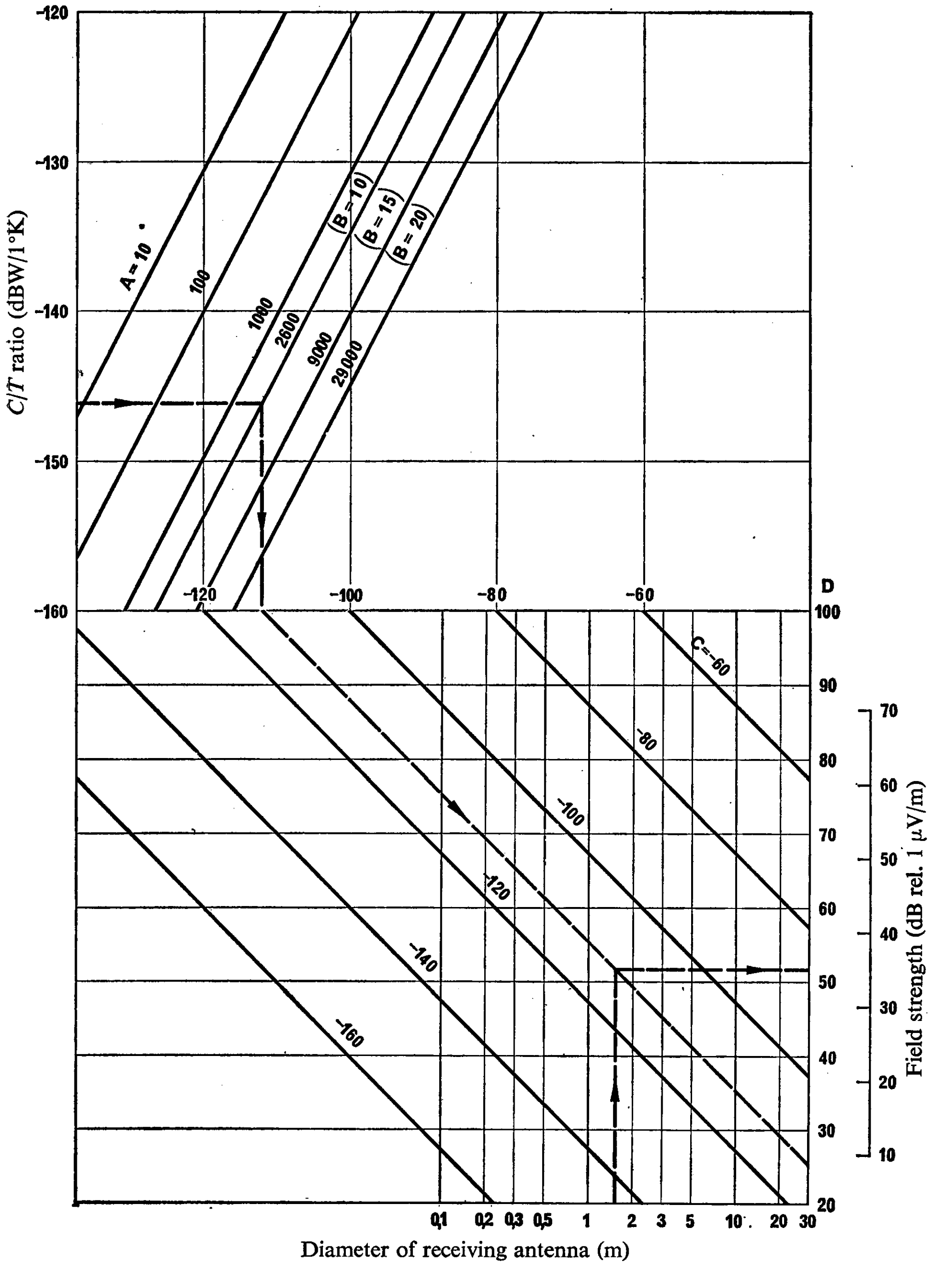

FIGURE 2*b*

A: noise temperature (°K)
B: noise figure (dB)
C: receiver carrier power (dBW)
D: e.i.r.p. of satellite (dBW)

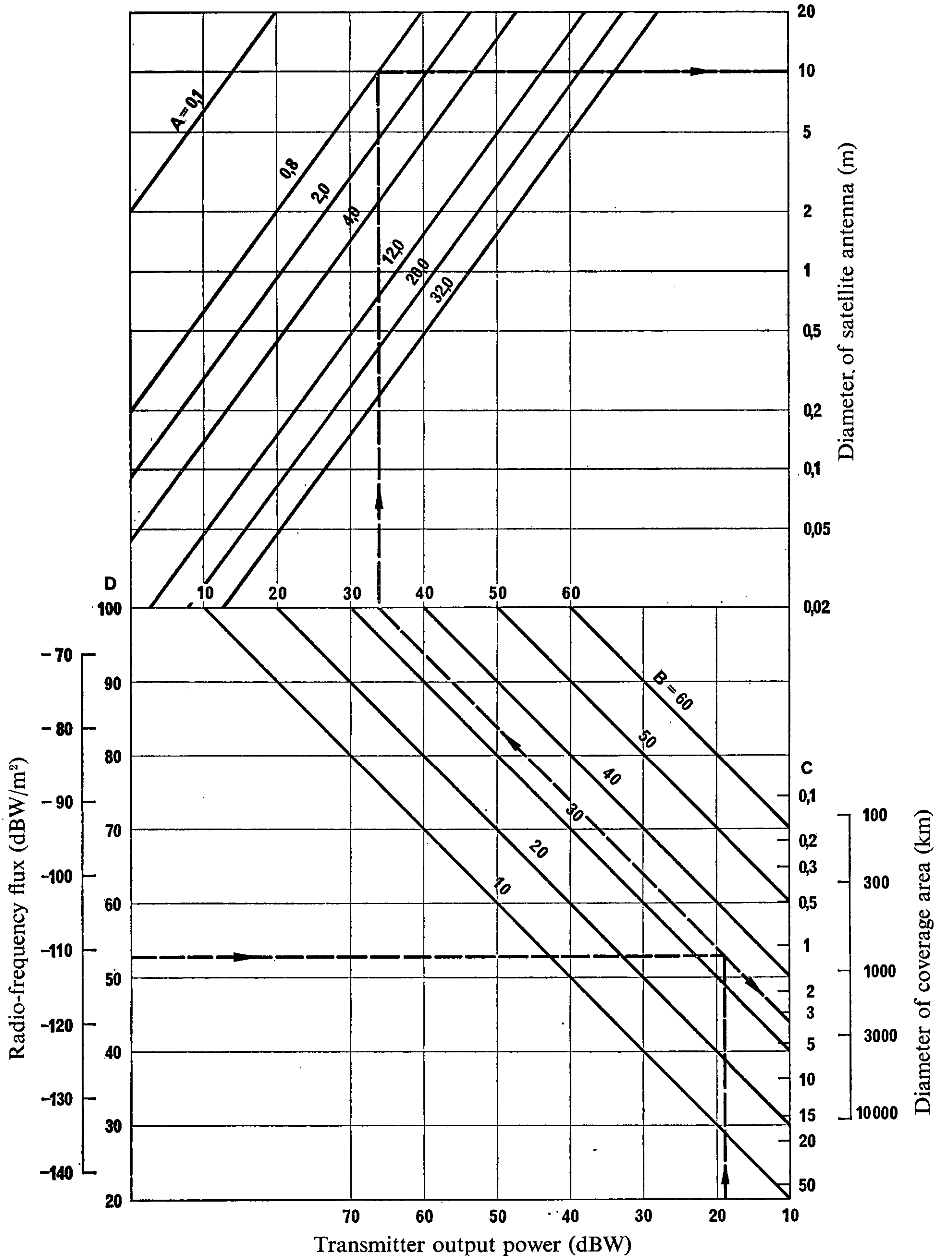

FIGURE 2c

A: frequency (GHz)
B: satellite antenna gain (dB)
C: half-power beamwidth (degrees)
D: e.i.r.p. (dBW)

REPORT 473 *

FEASIBILITY OF DIRECT BROADCASTING FROM SATELLITES

Characteristics of ground-receiving equipment for broadcasting-satellite systems

(Question 5-1/11)

(1970)

Several documents submitted to the Final Meetings of Study Groups IV, X and XI in September 1969 [1, 2, 3] deal in some detail with the potentially required characteristics of receivers for both direct and community broadcasting-satellite systems.

One document submitted by the United States of America [4] presents information on the estimated performance and cost of equipment which, when added to an existing television receiver, permits the reception of signals from broadcasting satellites.

In [4] the equipments discussed include the receiving antennae, and electronics that would amplify the received signal and, where required, perform the conversion of frequency and/or modulation format of the signal to make it compatible with the frequency and modulation format of existing television receivers. Currently possible performance and costs are given, and the anticipated changes through 1975 are considered.

The consensus of information submitted to the C.C.I.R. in response to Questions 5-1/11 and 23/11 (34/10) indicates that by 1975 or earlier it will be technically possible to provide a satellite broadcasting service to then-existing television receivers equipped with auxiliary equipment such as that considered in [4].

It is considered desirable that Study Group 11 include, in its studies of television receivers, receivers and auxiliary apparatus required to permit reception from television broadcasting satellites. Such studies should include not only frequency aspects, but also cost, producibility, compatibility with existing picture and transmission standards, and all other relevant aspects. Timely studies of these matters should facilitate and accelerate the orderly introduction of broadcasting-satellite service when and where authorized.

To facilitate and guide such studies the XIIth Plenary Assembly adopted Study Programme 5-1E/11. Administrations are invited to consider the Reports cited above, to conduct studies as proposed in Study Programme 5-1E/11, and to report their findings to the C.C.I.R.

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3. C.C.I.R. Doc. IV/310 (XI/152) (U.S.A.), 1966–1969.
4. C.C.I.R. Doc. IV/312 (XI/154) (U.S.A.), 1966–1969.

* This Report, which was adopted unanimously, and Study Programme 5-1E/11 have been brought to the attention of Study Groups 1, 4 and 10.

REPORT 474 *

BROADCASTING-SATELLITE SERVICE (SOUND BROADCASTING)

Frequency-sharing between the broadcasting-satellite service and terrestrial services in technically suitable bands

(1970)

1. Band 5 (LF), band 6 (MF) and the lower part of band 7 (HF) are technically unsuitable for satellite broadcasting [1].

2. Band 7 (HF)

Frequency-sharing between the broadcasting-satellite service and the terrestrial services would be technically feasible in band 7; however, the problems involved would be at least as difficult as those now existing between terrestrial stations. Atmospheric noise levels are such that frequencies in the upper part of the band around 25 MHz appear to be those most suitable for amplitude-modulated sound broadcasting service from satellites, in band 7 [1, 2].

3. Bands 8 and 9 (VHF and UHF)

3.1 Frequency-sharing between the broadcasting-satellite service and terrestrial services is not feasible except under one or more of the following conditions [3, 4]:

3.1.1 Considerably lower protection ratios than those contained in Recommendation 412, Report 462, Recommendation 418-2 and Report 479 are applied.

3.1.2 Field strengths having values considerably lower than those required for emissions from terrestrial broadcasting stations as shown in Recommendation 412 and Report 462 are utilized by the broadcasting-satellite service.

3.1.3 Power flux-density limitations are placed on emissions from either satellite and/or terrestrial broadcasting stations within areas where interference may occur, noting that a satellite may produce interference over geographical areas of continental size.

3.1.4 Confinement of the potential zone of coverage for the broadcasting-satellite service to those areas where emissions from co- and adjacent-channel terrestrial stations do not exist at present and where the satellite service could be protected from interference due to terrestrial stations that might be installed in the future (primarily rural or sparsely settled areas).

3.2 It is considered that these conditions for sharing would often be detrimental to either or both the terrestrial and broadcasting-satellite services.

3.3 The possibilities of sharing between the broadcasting-satellite service and non-broadcasting terrestrial services in band 9 requires further study.

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* This Report, which was adopted unanimously, furnishes a partial reply to Question 20-1/10. It has been brought to the attention of Study Group 4.

4. Band 10 (SHF)

4.1 Sharing might be possible between satellite and terrestrial stations on condition that frequency modulation is used for the satellite service.

4.1.1 In low latitude regions where monsoons are a major phenomenon, attenuation due to rainfall may limit the use of this band by broadcasting-satellite stations to the frequency range below 10 GHz. In these geographical areas, the lower part of band 10 (and the upper part of band 9) appears to be technically suitable [5]; however, this requires further study.

4.2 The possibilities of sharing between the broadcasting-satellite service and non-broadcasting terrestrial services in band 10 requires further study.

5. Conclusions

If a broadcasting-satellite service is to be established in band 7, sharing with terrestrial broadcasting services may be possible. In bands 8 and 9, exclusive allocations are required unless the conditions tabulated in §§ 3.1.1 to 3.1.4 can be accepted. Sharing with terrestrial broadcasting services appears to be feasible in band 10

In tropical regions excessive attenuation due to rainfall may limit the use of band 10 to frequencies well below 10 GHz, as discussed in § 4.1.1.

Sharing between satellite broadcasting and terrestrial non-broadcasting services requires further study.

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REPORT 475 *

BROADCASTING-SATELLITE SERVICE (TELEVISION)

Frequency-sharing between the broadcasting-satellite service and terrestrial services in technically suitable bands

(Question 5-1/11)

(1970)

1. Bands 8 and 9 (VHF and UHF)

1.1 Frequency-sharing between the satellite and terrestrial broadcasting services for television in bands 8 and 9 is not feasible except under one or more of the following conditions [1, 2, 3 and 4]:

1.1.1 considerably lower protection ratios than those contained in Recommendation 418-2 and Report 479, are applied;

1.1.2 field strengths having values considerably lower than those required for emissions from terrestrial broadcasting stations as shown in Recommendation 417-2 are utilized by the broadcasting-satellite service;

1.1.3 power flux-density limitations are placed on emissions from either the satellite and/or terrestrial broadcasting stations within areas where interference may occur, noting that a satellite may produce interference over areas of continental size;

1.1.4 confinement of the potential zone of coverage for the broadcasting-satellite service to those areas where emissions from co- and adjacent-channel terrestrial stations do not at present exist and where the satellite service could be protected from interference due to terrestrial stations that might be installed in the future (primarily rural or sparsely settled areas).

1.2 It is considered that these conditions for sharing would often be detrimental to either or both the satellite and terrestrial broadcasting services.

1.3 The possibilities of sharing between the broadcasting-satellite service and non-broadcasting terrestrial services in band 9 also requires further study by the C.C.I.R.

2. Band 10 (SHF)

2.1 According to a preliminary theoretical study in [4], sharing between the broadcasting-satellite service and the terrestrial broadcasting service is feasible in band 10 without excessive geographic restrictions, on the condition that the broadcasting-satellite service utilize frequency-modulation with peak-to-peak deviation of sufficient magnitude. However, in the absence of experimental data, the difficulties of establishing high-latitude services and of providing service areas of various forms and sizes, further study is required before precise and definitive criteria for sharing can be derived.

2.1.1 In low latitude regions where monsoons are a major phenomenon attenuation due to rainfall may limit the use of this band by broadcasting-satellite stations to the frequency range well below 10 GHz. In these regions, the lower portion of band 10 (and the upper portion of band 9) appears to be technically suitable [5]; however, this requires further study.

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* This Report, which was adopted unanimously and is a partial reply to Question 5-1/11, has been brought to the attention of Study Group 4.

2.1.2 The possibilities of sharing between the broadcasting-satellite service and non-broadcasting terrestrial services in band 10 are examined in [6], but also require further study.

3. Conclusions

If a broadcasting-satellite service is to be established in bands 8 or 9, exclusive allocations are required, except where the conditions tabulated in §§ 1.1.1 to 1.1.4 can be accepted. Sharing with the terrestrial broadcasting service appears to be feasible in band 10, if frequency modulation is used for the satellite service.

In tropical regions excessive attenuation due to rainfall may limit the use of band 10 to the region well below 10 GHz, as discussed in § 2.1.1.

Sharing between the broadcasting-satellite service and non-broadcasting terrestrial services, particularly in bands 9 and 10, and use of existing broadcast bands for the broadcasting-satellite service, require further study.

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