INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

DOCUMENTS OF THE

XIth PLENARY ASSEMBLY

OSLO, 1966

VOLUME III

FIXED AND MOBILE SERVICES
STANDARD-FREQUENCIES AND TIME-SIGNALS
MONITORING OF EMISSIONS

Published by the
INTERNATIONAL TELECOMMUNICATION UNION
GENEVA, 1967

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ADDENDUM No. 1

to

VOLUME III OF THE DOCUMENTS
OF THE XIth PLENARY ASSEMBLY OF THE C.C.I.R.
Oslo, 1966

Note by the Director, C.C.I.R.

1. During the Special Meeting of Study Group XIII (Mobile services), Geneva, 1967, the Interim Meetings of Study Groups VII (Standard-frequencies and time-signals) and VIII (International monitoring), Boulder, Colorado, 1968 and the Interim Meeting of Study Group XIII, Geneva, 1968, it was decided that, in view of the urgency of commencing work on the problems involved, certain Draft Questions and Study Programmes should be circulated to Administrations for approval by correspondence, in accordance with Article 14, § 2(1) of the International Telecommunication Convention, Montreux, 1965.

Each of the texts submitted has received more than the twenty approvals necessary for their adoption from the Members and Associate Members of the I.T.U. and they have, in consequence, now become official Questions and Study Programmes of the C.C.I.R. (see Administrative Circulars A.C./124 of 7 November, 1968 and A.C./126 of 25 November, 1968 (Study Groups VII and VIII) and A.C./106 of 4 August, 1967 and A.C./128 of 18 December, 1968 (Study Group XIII)).

These texts are:

— *Question 5/VII*, which is reproduced on a separate sheet numbered 318;

— *Question* 2-1/*VIII*, which is reproduced on a separate sheet numbered 426*a*;

— *Questions 9/XIII, 10/XIII, 11/XIII and 12/XIII*, which are reproduced on separate sheets numbered 270*a* to 270*c*;

— *Study Programmes 2-1A/XIII and 6A/XIII*, which are reproduced on separate sheets numbered 426*a*, 426*b* and 265*a*.

2. The text of Question 2-1/VIII is intended to replace the existing text of Question 2/VIII, which will be recommended for deletion to the XIIth Plenary Assembly.

3. One Administration, while approving the text of Question 12/XIII, recommends that the words " without speech " should be deleted from the text in the footnote. This proposition will be discussed at the next meeting of Study Group XIII.

4. Advantage has been taken of the issue of this Addendum to notify the following corrections to Volume III:

Page 10. In the list, replace " Recommendation 429 " by " Recommendation 429-1 ".

Page 146. Replace equation (2) by:

$$“ P' = P_0\, \theta'_0 \varphi'_0 / K ”.$$

Page 147. Replace equation (3) by:

$$“ G' = qP_0/P' = qK/\theta'_0 \varphi'_0 ”.$$

In paragraph 6, replace " asuumed " by " assumed ".

Page 148. The paragraph " For distances less .... over the route " should follow the expression " Δ_m = vertical ..... (degrees) ".

Page 149. In Fig. 1, on the axis of ordinates, replace " 110 " by " 200 ".

Page 291. Concerns the French text only.

Page 326. In the figure the words " Resolving power " should be removed from the axis of ordinates and replaced above the " ←------→ " at the top.

Page 327. Concerns the French text only.

Page 381. In the 7th line of § 4.1.3, replace " Report 275-1 " by " Report 279-1 ".

Page 414. In Fig. 3, insert " E-plane " over the left-hand figures and " H-plane " over the right-hand figures.

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FIXED SERVICES	**Recommendations of Section C (Fixed services)** **Reports of Section C (Fixed services)** **Questions and Study Programmes assigned to Study Group III (Fixed service systems) – Opinions and Resolutions of interest to this Study Group – Lists of documents**
MOBILE SERVICES	**Recommendations of Section D (Mobile services)** **Reports of Section D (Mobile services)** **Questions and Study Programmes assigned to Study Group XIII (Mobile services) – Opinions and Resolutions of interest to this Study Group – Lists of documents**
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DISTRIBUTION OF THE TEXTS OF THE XIth PLENARY ASSEMBLY OF THE C.C.I.R. AMONG VOLUMES I-VI

- Volumes I to VI of the documents of the XIth Plenary Assembly contain all the C.C.I.R. texts at present in force.
- For Questions and Study Programmes, the final (Roman) numeral indicates the Study Group to which the text has been assigned. The plan on page 5 shows the Volume in which the various texts of that Study Group can be found.
- Recommendations, Reports, Opinions and Resolutions which have been amended by the XIth Plenary Assembly, have retained their original number, followed by the indication 1 (e.g.: Recommendation 326-1). which is not shown in the Table below. Further details on the numbering system appear in Volume VI.

1. Recommendations

Number	Volume	Number	Volume	Number	Volume
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48, 49	V	239	I	314	IV
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80	V	246	III	335–349	III
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2. Reports

Number	Volume	Number	Volume	Number	Volume
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32	V	195–198	III	297–316	V
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(1) Published separately.

3. Opinions

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ARRANGEMENT OF VOLUMES I TO VI OF THE DOCUMENTS OF THE XIth PLENARY ASSEMBLY OF THE C.C.I.R.

(Oslo, 1966)

VOLUME I	Emission. Reception. Vocabulary (Sections A, B, K and Study Groups I, II and XIV).
VOLUME II	Propagation (Section G and Study Groups V and VI).
VOLUME III	Fixed and mobile services. Standard-frequencies and time-signals. International monitoring (Sections C, D, H and J and Study Groups III, XIII, VII and VIII).
VOLUME IV	Radio-relay systems. Space systems and Radioastronomy (Sections F and L and Study Groups IX and IV).
VOLUME V	Sound broadcasting and Television (Section E, Study Groups X, XI and XII and the CMTT).
VOLUME VI	List of participants. Minutes of the Plenary Meetings. Resolutions of a general nature. Reports to the Plenary Assembly. Lists of documents in numerical order.

Note 1. – To facilitate references, the pagination in the English and French texts is the same.

Note 2. – At the beginning of Volume VI will be found information concerning the XIth Plenary Assembly of the C.C.I.R. and the participation at this meeting, on the presentation of texts (Definitions, origins, numbering, complete lists, etc.), together with general information on the organization of the C.C.I.R.

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RECOMMENDATIONS OF SECTION C (FIXED SERVICES)

RECOMMENDATION 75

CLASSIFICATION AND ESSENTIAL CHARACTERISTICS OF FEED-BACK SUPPRESSORS

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

CONSIDERING

that the feedback suppressors now generally used are of a type, the operation of which is sufficiently independent of the characteristics of those at the opposite end of the circuit;

UNANIMOUSLY RECOMMENDS

that no classification of types nor terminology should be adopted.

Essential characteristics

The essential characteristics of the feedback suppressors, used on radiotelephone circuits in the United Kingdom and in the United States of America for fixed services, are described respectively in Docs. 49 and 51, Geneva, 1951. These are in substantial accord with the characteristics described in C.C.I.F., 1950-1951, 5th Study Group, Doc. 7, Question 2.

RECOMMENDATION 100

REDUCTION OF OCCUPIED BANDWIDTH AND TRANSMITTER POWER IN RADIOTELEPHONY

(Question 1/III)

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

CONSIDERING

(a) the urgent need for improved use of the radio-frequency spectrum, particularly in the range below 30 MHz;

(b) that a very great improvement in the use of the spectrum will arise from the replacement of double-sideband by single-sideband technique (see Recommendation 335-1, §§ 2.1 and 2.2);

(c) that improvements can be obtained by the use of noise reducers and devices enabling the average percentage of modulation to be maintained at a high level, e.g. peak-clipping devices (see Recommendation 339-1);

RECOMMENDS

1. that Administrations should, whenever possible, make use of single-sideband systems in preference to double-sideband systems *;

2. that noise reducers should be employed at the receiving terminal of all circuits, where an improvement in signal-to-noise ratio can be obtained **;

3. that devices should be employed at the transmitting terminal of all circuits, to enable the average percentage of modulation to be maintained at a high level (for example, peak-clipping devices). With the use of these devices, adequate precautions must be taken to prevent radiation outside the necessary bandwith (for example, by the use of an adequate low-pass filter after the device) ***.

RECOMMENDATION 106

VOICE-FREQUENCY TELEGRAPHY ON RADIO CIRCUITS

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

CONSIDERING

(a) that diversity reception is not a common practice on radiotelegraph circuits;

(b) that, when voice-frequency equipment is used on radio circuits at frequencies lower than about 30 MHz, the quality of these circuits will, in general, be insufficient if no means of diversity reception is provided;

(c) that, in the presence of fading, space- or frequency-diversity gives comparable improvements in the quality of reception of telegraph signals transmitted over radio channels;

(d) that, for adequate frequency diversity, it appears necessary that the frequencies which are used in combination to obtain this diversity should differ by at least 400 Hz;

(e) that space diversity needs only half the bandwidth and less power for each telegraph channel, as compared with frequency diversity, but usually requires more equipment;

UNANIMOUSLY RECOMMENDS

1. that, when voice-frequency telegraph systems are used on radio circuits at frequencies lower than about 30 MHz, diversity reception should be used on the individual voice-frequency channels;

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* An improvement of signal-to-noise ratio, or a reduction in power of at least 9 dB, is obtained by the use of single-sideband systems instead of double-sideband systems.

** The improvement, which may be obtained in practice, by the use of a noise reducer is dependent upon the signal-to-noise ratio at the input to the noise reducer (for example, an improvement of the order of 10 dB may be obtained on radiotelephone circuits of good commercial quality).

*** The improvement, which may be obtained in practice, is dependent upon the original average percentage modulation of the transmitter. Improvement up to 6 dB may be obtained in practice.

2. that, whenever practicable, space diversity should be used in preference to frequency diversity;

3. that, for frequency diversity, the channel frequencies used in combination should have a separation of at least 400 Hz so that adequate diversity effects may be obtained.

RECOMMENDATION 162-1

USE OF DIRECTIONAL ANTENNAE IN THE BANDS 4 TO 28 MHz

(Question 10/III)

The C.C.I.R., (1953 - 1956 - 1966)

CONSIDERING

(a) that there is serious congestion in the fixed-service bands between 4 and 28 MHz;

(b) that occupancy of the radio-frequency spectrum is represented, not only by occupancy in bandwidth and time, but also by the spatial distribution of the radiated power;

(c) that radiation outside the directions necessary for the service can be effectively reduced by the use of directional antennae;

(d) that Articles 12 and 14 of the Radio Regulations, Geneva, 1959, would seem to justify explicit requirements for the use of directional antennae in these bands;

(e) that the Panel of Experts, in Recommendation No. 13 of its Final Report, Geneva, 1963, advocates the use of directional antennae for transmission and reception in the fixed service;

(f) that the request by the Panel of Experts in Recommendation No. 38 of its Final Report, and the urgent question of the I.F.R.B., Question 10/III, ask for specification of reasonable standards of directivity for antennae in the various types of radio services in the bands between 4 and 28 MHz, with due regard to economy of cost;

(g) that the adoption of minimum standards for directional antennae would contribute to the solution of frequency sharing problems;

(h) that antenna performance materially better than these minimum standards are attainable at economic cost using modern technique;

UNANIMOUSLY RECOMMENDS

1 Definitions

that the following definitions should be used in specifying the performance of directional antennae;

1.1 *Directive gain (G)*

The ratio of the power radiated from a reference antenna to the power radiated from the antenna being considered, both antennae producing in the wanted direction, the same field at the same distance. It is convenient for present purposes that the reference antenna should be an isotropic radiator in free space.

1.2 *Service sector (S)*

The horizontal sector containing the main beam of the antenna radiation and including the direction required for service. It is very close to twice the angular width of the main beam measured to the half-power (– 3 dB) points.

1.3 *Interference sector (I)*

The horizontal sector outside the main beam

$$I^\circ = 360^\circ - S^\circ$$

1.4 *Minimum standard antenna*

The antenna having the specified minimum characteristics as regards directive gain and service sector at its operating frequency or frequencies.

1.5 *Economic standard antenna*

The antenna having specified characteristics as regards directive gain and service sector at its operating frequency or frequencies which are justifiable on economic grounds (i.e. by savings in the cost of providing a given transmitter output power).

1.6 *Antenna directivity factor (M)* *

The ratio of the power flux density in the wanted direction to the average value of power flux density at crests in the antenna directivity pattern in the interference sector. This is equivalent to the average improvement in signal-to-interference ratio achieved by using the actual antenna in place of an isotropic radiator in free space;

2. that the minimum standard antenna should have a directivity factor given by

$$M = 0{\cdot}1 f^2$$

f being the operating frequency in MHz;

3. that the economic standard antenna should have a directivity factor given by

$$M = 0{\cdot}25 f^2;$$

4. that, for a radiated power of 5 kW or greater, the performance of the antenna used should not be worse than that of the minimum standard antenna;

5. that, for a radiated power of 10 kW or greater, antennae having performances not worse than that of the economic standard antenna should be used to the extent practicable;

6. that, for transmitter powers below 5 kW, the power flux density in the interference sector should not exceed that radiated in this sector from the minimum standard antenna with a total radiated power of 5 kW;

7. that, in the interests of reducing the effects of interference, the performance of the receiving antenna should not be worse than that of the minimum standard antenna and should, as far as practicable, attain that of the economic standard antenna.

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* The derivation of the value of the directivity factor for any given antenna is explained in Report 356.

Explanatory notes

The values of directive gain and service sector appropriate to the specified *M* values for the minimum standard antenna and the economic standard antenna respectively are given in the following table:

Operating frequency *f*(MHz)	Minimum standard antenna			Economic standard antenna		
	M	*G*(dB)	*S*°	*M*	*G*(dB)	*S*°
5	2·5	13·8	54	6·25	17·5	35
10	10	16·6	39	25	20·4	25
15	22·5	18·3	32	57	22·1	21
20	40	19·4	28	100	23·3	18

The antenna gain relative to a half-wave dipole above earth may be obtained by subtracting 8 dB from the value of *G*. It should be noted that the *S* value is the minimum bound at the directive gain specified and has been derived on the assumption that at least 40% of the total power is radiated in the main beam (a value appropriate to many rhombic antennae). Where (as is commonly the case) the (power) gain of the antenna (No. 99 of the Radio Regulations) is known, a suitable adjustment should be made to account for the efficiency of the antenna in deriving the directive gain.

No preferred polarization or type of antenna is established. Horizontal polarization offers better round reflection characteristics and, for receiving, some reduction of interference due to man-made noise. Where reflection over sea water or over earth of very high conductivity takes place, the use of vertical polarization can enhance the low-angle performance needed for long paths. This important consideration is reflected in the computation of *M*, which includes a weighting factor $10/\Delta$, where Δ is the vertical angle of optimum radiation. There is no requirement for the transmitting and receiving antennae to have the same polarization characteristics because of the randomisation of the polarization in the ionospheric transmission process.

The *M*-factors chosen are largely based upon the measured performance of typical rhombic antennae and typical antenna-arrays. The radiation characteristics of single rhombic antennae in the interference zone, are in general, somewhat inferior to other types of antenna (e.g. halfwave antenna arrays), a fact which is reflected in the *M*-factor. Provided the parameters are correctly chosen, the performance of antennae of differing types possessing the same *M*-factor are comparable.

RECOMMENDATION 166-1

UNIT OF QUANTITY OF INFORMATION

The C.C.I.R., (1956 - 1966)

UNANIMOUSLY RECOMMENDS

the following definition of the unit of quantity of information:

" the unit of quantity of information corresponds to a *message unit* consisting of a random choice between two equally probable signals." (Xth General Assembly of U.R.S.I., Sydney, 1952). This unit may be designated by the word *bit*.

RECOMMENDATION 240 *

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS

(Question 1/III — Study Programme 1A/III)

The C.C.I.R., (1953 - 1956 - 1959)

CONSIDERING

that knowledge of the signal-to-interference protection ratios for various types of service is needed;

RECOMMENDS

1. that the values of signal-to-interference ratios for stable conditions, below which harmful interference occurs, can be used in conjunction with the fading allowances in the Annex to Recommendation 340;

2. that the values shown in the Table are appropriate to emissions indicated.

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* This Recommendation replaces Recommendation 163. The R.P. of Bulgaria, the Ukrainian S.S.R., the Czechoslovak S.R. and the U.S.S.R. reserved their opinion on this Recommendation.

TABLE

Minimum protection ratios and frequency separations required under stable conditions

Wanted signal	Interfering signal																			
Type of service	A1 50 bauds([1])				A1 100 bauds				F1 50 bauds $2D$ = 280 Hz([1])				F1 100 bauds $2D$ = 400 Hz				Broadcast([5])			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	(dB)	(kHz)			(dB)	(kHz)			(dB)	(kHz)			(dB)	(kHz)			(dB)	(kHz)		
A1–50 baud teleprinter B = 500 Hz	11	0·36	0·44	1·14	([2]) 12	([2]) 0·25	([2]) 0·35		13	0·46	0·54	1·24	([2]) 3	([2]) 0·40	([2]) 0·55					
F1–50 baud teleprinter $2D$ = 280 Hz, B = 500 Hz	1	0·2	0·28	0·6					7	0·32	0·39	0·67								
F1–50 baud teleprinter $2D$ = 280 Hz, B = 3000 Hz																	([3]) 18	([3]) 3	([3]) 4·5	([3]) 7·5
F1–50 baud teleprinter $2D$ = 400 Hz, B = 500 Hz					([2]) 3	([2]) 0·35	([2]) 0·50						([2]) 2	([2]) 0·45	([2]) 0·60					
F1–171 baud ARQ system $2D$ = 400 Hz, B = 500 Hz					([4]) 4	([4]) 0·40	([4]) 0·55						([4]) 4	([4]) 0·50	([4]) 0·70					
F4–phototelegraphy, 60 r.p.m. B =1000 Hz					15	1·00	1·20						15	1·10	1·20					

In the column "Type of service", B represents the receiver bandwidth and $2D$ represents the total frequency shift. Columns numbered 1 give the limiting values of signal-to-interference ratio (dB) when the occupied band of the interfering emission either falls entirely within the pass-band of the receiver, or covers it completely. Columns numbered 2, 3 and 4 indicate the frequency separation necessary between a wanted and an interfering signal, when the level of the latter is 0, 6 or 30 dB higher than the wanted signal.

([1]) Bandwidth of interfering signals limited to 500 Hz;
([2]) For a character error rate of 1/10000;
([3]) For a character error rate of 1/1000;
([4]) For a traffic efficiency of 90 %;
([5]) Average modulation degree of 40 %; for this test the sideband components extended to ± 9 kHz.

RECOMMENDATION 246-1

FREQUENCY-SHIFT KEYING

(Question 8/III)

The C.C.I.R., (1951 - 1953 - 1956 - 1959 - 1966)

CONSIDERING

(a) that frequency-shift keying is employed in radiotelegraphy in the fixed service and that its use has also been extended to the mobile service;

(b) that it is desirable to adapt the frequency-shift used to the modulation rate;

(c) that traffic interruptions should be reduced to a minimum by avoiding frequent changes of the shift employed;

(d) that it is often necessary to employ the same radio transmitter to work with more than one receiving station;

(e) that it is desirable to standardize the main operating characteristics of systems employing frequency-shift keying;

(f) that various technical factors influence the choice of operating characteristics in such systems, in particular:

- economy of bandwidth and the consequent need to control the shape of the transmitted signals,
- signal distortion due to propagation conditions,
- instability of the characteristics of certain transmitter and receiver elements (such as oscillators, filters or discriminators); this instability being one of the reasons for the relatively large shift employed in many existing types of equipment;

(g) that difficulties can arise from the use of terms " mark " and " space " on teletype circuits and also that the C.C.I.T., at its VIIth Plenary Assembly, issued Recommendation I.4 introducing new terms; these terms have been published by the I.T.U. in the " List of Definitions of Essential Telecommunication Terms ", Part I, General Terms, Telephony, Telegraphy, June 1957;

UNANIMOUSLY RECOMMENDS

1. that it is too early to standardize actual values of frequency-shift, but that every effort should be made to achieve this as quickly as possible for emissions using only two frequencies; and to assist in this, the characteristics shown below should be used as far as possible;

2. that the value of the frequency-shift employed should be the lowest compatible with the maximum modulation rate regularly used, the propagation conditions and the equipment stability;

3. that for frequency-shift systems working on two conditions only (i.e. single-channel or time-division multiplex systems) and operating between about 3 MHz and 30 MHz, the preferred values of frequency-shift are 200 Hz, 400 Hz and, for modulation rates above 250 bauds, 500 Hz;

4. that the values 140 Hz, 280 Hz and 560 Hz may be used provisionally, but 560 Hz should not be adopted for new systems;

5. that the value of the frequency-shift should, if possible, be maintained within $\pm$ 3 % of its nominal value and, in any case, within $\pm$ 10 %;

6. that for circuits using the Morse code, the higher frequency should correspond to the mark signal, and the lower frequency should correspond to the space signal;

7.* that for circuits using the International Alphabet No. 2 code with start-stop apparatus, the higher frequency should correspond to the start signal (position *A*) and the lower frequency to the stop signal (position *Z*);

8.* that, for telex circuits using the International Alphabet No. 2 code directly on the radio circuit, the higher frequency should correspond to the C.C.I.T.T. " free circuit condition " (position *A*) and the lower frequency to the C.C.I.T.T. " idle-circuit condition " (position *Z*);

9.* that for channels of a 7-unit automatic repetition system, which are referred to in the Annex to Recommendation 342-1 as directly keyed channels (e.g. channel *A* of a two-channel system), the higher frequency should correspond to the code elements shown as letter *A* and the lower frequency to the code elements shown as letter *Z*. For the channels which are to have reversed keying (e.g. channel *B* of a two-channel system), the higher frequency should correspond to the code elements shown as letter *Z* and the lower frequency to the code elements shown as letter *A*.

RECOMMENDATION 335-1

USE OF RADIO LINKS IN INTERNATIONAL TELEPHONE CIRCUITS

The C.C.I.R., (1951 – 1963 – 1966)

CONSIDERING

(a) that, at the present time, radiotelephone systems connecting the various countries usually employ carrier-frequencies below about 30 MHz **;

(b) that the use of such a radio link, in a long-distance telephone circuit, implies certain special conditions, which introduce particular difficulties not encountered when purely metallic connections are used;

(c) that such a radiotelephone circuit differs from a metallic circuit in the following ways;

c.a such a radiotelephone circuit is subject to attenuation variation with the special difficulty of fading;

c.b such a radiotelephone circuit suffers from noise caused by atmospherics, the intensity of which may reach, or even exceed, a value comparable with that of the signal which it is desired to receive;

c.c special precautions are necessary in the setting up and maintenance of such a radiotelephone circuit, to avoid disturbance of the radio receiver by any radio transmitter and especially by its own radio transmitter;

c.d to maintain the radiotelephone link in the best condition from a point of view of transmission performance, it is necessary to take special measures to ensure that the radio transmitter

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* When modification of equipment is necessary, it is recognized that it may take some time before the recommendations of these paragraphs can be implemented on circuits between different Administrations.

** Further reference to 30 MHz in this Recommendation means " about 30 MHz ".

always operates, as far as possible, under conditions of full loading, whatever may be the nature and the attenuation of the telephone system connected to the radiotelephone circuit;

c.e it is necessary to take measures to avoid or correct conditions of abnormal oscillation or crosstalk;

c.f although the recommended frequency band, to be effectively transmitted by international landline circuits, has been determined by a study of the requirements of the human ear, this band (for a radiotelephone circuit operating at a frequency below 30 MHz), may be limited by the necessity of obtaining the maximum number of telephone channels in this part of the radio-frequency spectrum and so that each telephone channel does not occupy a radio-frequency band larger than necessary;

c.g in general, such a radiotelephone circuit is a long distance international circuit giving telephone service between two extended networks, and this fact is of great importance from two points of view:

c.g.a on the one hand, international conversations, in general, are of great importance to the subscribers and, on the other hand, they are made in languages which are not always their mother tongue, so that high quality reception is particularly important;

c.g.b the public should not be deprived of a very useful service under the pretext that it does not always satisfy the degree of excellence desirable for long distance communication;

UNANIMOUSLY RECOMMENDS

1. Circuits above 30 MHz

that between fixed points, telephone communications should be effected wherever possible by means of metallic conductors, or radio links using frequencies above 30 MHz to make the allocation of radio frequencies less difficult; where this can be realized, the objective should be to attain the transmission performance recommended by the C.C.I.T.T. for international telephone circuits on metallic conductors;

2. Circuits below 30 MHz

2.1 that, since it becomes necessary to economize in the use of the frequency spectrum, when considering international circuits which consist mainly of single long-distance radio links operating on frequencies less than 30 MHz, it is desirable to use single-sideband transmission to the maximum extent possible, to employ a transmitted band less than the 300 to 3400 Hz recommended by the C.C.I.T.T. for landline circuits and, preferably, to reduce the upper frequency to 3000 Hz or less, but not below 2600 Hz, except in special circumstances;

2.2 that, although it will be necessary to tolerate large variations in noise level on such a radiotelephone circuit, every possible effort should be made to obtain minimum disturbance to the circuit from noise and fading by the use of such techniques as full transmitter modulation, directional antennae and single-sideband operation;

2.3 that, during the time that such a radiotelephone circuit is connected to an extension circuit equipped with echo suppressors, the intensity of disturbing currents should not be sufficient to operate the echo suppressor frequently;

2.4 that such a radiotelephone circuit should be provided with a reaction suppressor (voice-operated switching device), to avoid singing or echo disturbance on the complete circuit;

2.5 that such a radiotelephone circuit should be equipped with automatic gain control to compensate automatically, as far as possible, for the phenomenon of fading;

2.6 that the terminal equipment of such a radiotelephone circuit should be such that it may be connected, in the same way as any other circuit, with any other type of circuit;

2.7 that, where privacy equipment is used, this equipment should not appreciably affect the quality of telephone transmission;

2.8 that, when suitable automatic devices are not provided, the circuit controls should be adjusted, as often as necessary, by an operator to ensure optimum adjustment of transmitter loading, received volume and the operating conditions of the reaction suppressor.

Note. – Although the requirements contained in § 2 of this Recommendation are much less severe than those imposed on international landline circuits, the objective remains to attain the same standards of telephone transmission in all cases. In view of this, it is desirable that the telephone systems connected to a radiotelephone circuit should conform to C.C.I.T.T. Recommendations covering the general conditions to be met by international circuits used for landline telephony, especially in respect of equivalent, distortion, noise, echoes and transient phenomena.

Bearing in mind the recommendations contained in §§ 1 and 2, it is desirable that in each particular case, Administrations and private operating agencies concerned should first reach agreement on how far the standards usually employed for international landline circuits may be attained in the case considered. If the technique of § 1 of the Recommendation can be used, the objective should be to obtain, as far as possible, the characteristics recommended by the C.C.I.T.T. for international landline circuits. Otherwise the Administrations and private operating agencies concerned should study the best solution from the point of view of both technique and economy.

RECOMMENDATION 336-1

PRINCIPLES OF THE DEVICES USED TO ACHIEVE PRIVACY IN RADIOTELEPHONE CONVERSATIONS

The C.C.I.R., (1951 – 1963 – 1966)

CONSIDERING

(a) that the devices referred to are intended to achieve privacy rather than secrecy in radiotelephone conversations;

(b) that, in the interest of maximum privacy, the details of the systems employed and of their performance, should be agreed upon between the Administrations and private operating agencies concerned;

UNANIMOUSLY RECOMMENDS

1. that the following statement of principles and characteristics of the devices concludes the study of Question 30, for radio circuits operating at frequencies less than about 30 Hz;

1.1 *Principles of the devices*

Two general types of system are used to achieve privacy in radiotelephone circuits operating at frequencies less than about 30 MHz;

1.1.1 *For double-sideband systems*

inverter systems, with or without wobbling of the carrier (i.e. rapid cyclic variation of the carrier frequency over a few hundred hertz), the speech band being inverted about a fixed frequency;

1.1.2 *For single-sideband and independent-sideband systems*

band-splitting systems, in which the speech band is subdivided into equal frequency bands, the speech components in the sub-bands being interchanged, with or without frequency inversion, and, according to a prearranged sequence, to give " scrambled " speech. The process is reversed at the receiving terminal to reform the speech signals. Accurate synchronization of the switching processes at the two terminals is required;

1.2 *Characteristics of the devices*

1.2.1 the band-splitting system provides privacy superior to that obtained with the inverter system, but for satisfactory operation it can tolerate less distortion;

1.2.2 the apparatus is designed to reduce attenuation distortion and the levels of unwanted products of modulation and of carrier signals to a minimum. The extent of the permissible distortion due to the presence of the privacy devices is, in general, dependent on the type of privacy and is usually agreed between the Administrations or private operating agencies concerned;

1.3 *Location of the devices*

to facilitate control and maintenance and on the grounds of economy, the privacy apparatus is normally located at the point where the transmitting and receiving channels of a radiotelephone circuit are combined;

2. that, for frequencies above about 30 MHz, the details of the systems to be employed and of their performance should be agreed upon between the Administrations or private operating agencies concerned.

RECOMMENDATION 337 *

CHANNEL SEPARATION

The C.C.I.R., (1948 – 1951 – 1953 – 1963)

CONSIDERING

(a) that, in the more usual cases, the primary factors which determine frequency separation between channels include:

- the signal power required by the receiver;
- the interference power intercepted by the receiver, including that from interfering signals and from noise;

(b) that transmitters, in general, emit radiations outside the frequency bandwidth necessarily occupied by the emission;

(c) that many factors are involved, among which are the properties of the transmission medium (which are variable in character and difficult to determine), the characteristics of the receiver and, for aural reception, the discriminating properties of the human ear;

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* This Recommendation replaces Recommendation 97.

UNANIMOUSLY RECOMMENDS

1. that the required separation between channels should be calculated by the following method:
   - determine the signal power intercepted by the receiver;
   - determine the interfering power intercepted, including both noise and interfering signal;
   - determine, from these data, the degree of frequency separation that produces acceptable ratios of signal power to interfering power, for an acceptable percentage of the time. Account should be taken of the fluctuating nature both of the signal and of the interference, and, whenever appropriate, the discriminating properties of the human ear;
2. that, at every stage of the calculation, comparison should be made, as far as possible, with data obtained under controlled representative operating conditions, especially in connection with the final figure arrived at for the channel separation.

RECOMMENDATION 338-1

BANDWIDTH REQUIRED AT THE OUTPUT OF A TELEGRAPH OR TELEPHONE RECEIVER

(Question 1/III)

The C.C.I.R., (1953 – 1963 – 1966)

CONSIDERING

(a) the urgent need to determine the minimum separation between frequency assignments of stations operating on adjacent channels, in the range 10 kHz to 30 MHz;

(b) that the width of the frequency band, which is necessary at the output of the receiver, is one of the factors which determine the band of frequencies required for the overall system;

(c) that, for telegraphy, the permissible degree of distortion is not yet defined;

(d) that, for telephony, the bandwidth may depend, among other factors, upon the type of privacy equipment in use;

UNANIMOUSLY RECOMMENDS

1. that, for telegraphy, a provisional value for the bandwidth necessary at the output of the receiver, under average practical conditions, should be as follows:

1.1 for A1 emissions, the bandwidth in hertz, after the final detector stage, should be equal to 2·5 times the modulation rate in bauds;

1.2 for F1 emissions, the bandwidth in hertz after the discriminator, should be equal to 1·4 times the modulation rate in bauds.

The extent to which these values can be applied, to permit closer spacing of adjacent channels, depends upon the degree and speed of amplitude variations due to fading and upon the differential fading of the frequencies corresponding to the two significant conditions of modulation;

2. that, for telephony, as a compromise between intelligibility and economy of bandwidth, the bandwidth necessary, for each speech channel at the output of the receiver, should be as follows:

2.1 in accordance with Recommendation 335-1, the upper limit frequency should be reduced to 3000 Hz or less but not lower than 2600 Hz;

2.2 the lower frequency limit of speech channels should be 250 Hz, and that of programme transmission channels should be 100 Hz;

2.3 for systems employing commercial privacy equipment, the necessary bandwidth for satisfactory service may require the use of an upper limit frequency greater than 2600 Hz (e.g. in five-band privacy equipment the necessary bandwidth is 2750 Hz, the upper limit being 3000 Hz).

RECOMMENDATION 339-1

BANDWIDTHS AND SIGNAL-TO-NOISE RATIOS IN COMPLETE SYSTEMS

(Question 1/III)

The C.C.I.R., (1951 – 1953 – 1956 – 1963 – 1966)

CONSIDERING

that it is not yet possible to give a full and accurate answer to Question 1/III, but to assist in giving such an answer, it is desirable to classify the important points with which future study will have to deal;

UNANIMOUSLY RECOMMENDS

1. that meanwhile, the values given in Table I should be adopted as provisional values for the signal-to-noise ratio required for the class of emission concerned;

2. that, in further study relating to the minimum separation between frequencies of stations operating on adjacent channels, the factors detailed in the Annex should be taken into consideration.

TABLE I.

Signal to-noise ratios required
(Stable conditions (Note 6))

Class of emission	Audio bandwidth of receiver (kHz)	Audio signal-to-noise ratio (dB)	Bandwidth of receiver (kHz)	Ratio of peak radio-frequency signal-noise in a 6 kHz band (dB) (Note 1)
A1 telegraphy				
8 baud, low grade	1·5	− 4	3	− 7
24 baud	1·5	11	3	8
120 baud, recorder	0·6	10	0·6	0
50 baud, printer	0·25	16	0·25	2
A2 telegraphy				
8 baud, low grade	1·5	− 4	3	− 3 (Note 2)
24 baud	1·5	11	3	12 (Note 2)
F1 frequency-shift telegraphy				
120 baud, recorder	0·25	4	1·5	2
50 baud, printer	0·10	10	1·5	− 2
F3 telephony				
D is the frequency deviation (kHz)	3		$2M+2DK$	
M is the audio bandwidth (kHz)				
K is normally 1, but sometimes a higher value is necessary				
(The ratio of peak radio-frequency signal-to-noise in a 6 kHz band, is lower by $(4{\cdot}77 + 20 \log D/M)$ dB than that required for A3 double-sideband telephony)				
F4 Phototelegraphy				
Sub-carrier frequency-modulation single-sideband emission	3	15	3	12
Hellschreiber				
Frequency-shift	1·5	6	3	3
Telephony		(Note 3)		
Double-sideband, just usable quality, operator to operator (Note 4)	3	6	6	18
Double-sideband, marginally commercial (Note 5)	3	15	6	27
Double-sideband, good commercial quality (Note 5)	3	33	6	35(1)
Single-sideband and independent-sideband, Just usable quality, operator to operator (1 channel)	3	6	3	9
Marginally commercial (Note 5)				
1 channel	3	15	3	18(1)
4 channels	3	15	3 (2)	20 (1), (4)
Good commercial quality (Note 5)				
1 channel	3	33	3	26(1)
4 channels	3	33	3(2)	28 (1), (4)

(1) Assuming 10 dB improvement due to the use of noise reducers.
(2) Per channel.
(3) No. 466 of the Radio Regulations, Geneva, 1959, prohibits F3 emissions for the fixed services in the bands below 30 MHz.
(4) Assuming a nominal allowance for 4-channel loading. If amplifier load control is used, the margin will vary dependent upon the number of talkers.

Note 1. – Measured as the ratio of the r.m.s. signal corresponding to peak output of the transmitter and the r.m.s. noise in a 6 kHz band, assuming stable conditions.

Note 2. – Carrier keyed. Beat-frequency oscillator used.

Note 3. – For telephony, the figures in this column represent the ratio of the audio signal, as measured on a standard VU-meter, to the r.m.s. noise, for a bandwidth of 3 kHz. (The corresponding peak signal power, i.e., when the transmitter is 100% tone-modulated, is assumed to be 6 dB higher).

Note 4. – For 90% intelligibility of unrelated words.

Note 5. – When connected to the public service network.

Note 6. – These values are based on Doc. 138, Washington, 1950, Doc. 112, Geneva, 1951, and Doc. 11, The Hague, 1952.

ANNEX

FACTORS TO BE TAKEN INTO ACCOUNT FOR VARIOUS SERVICES IN DETERMINING THE MINIMUM SEPARATION BETWEEN THE FREQUENCIES OF STATIONS OPERATING ON ADJACENT CHANNELS

1. Required signal-to-interference ratios.

2. Necessary bandwidth for required intelligence.

3. Transmitters:
- out-of-band radiation,
- frequency instability.

4. Propagation:
- allowances for fluctuations due to absorption and fading.

5. Receivers:
- necessary bandwidth,
- attenuation slope,
- frequency instability.

6. Effect of:
- inequalities of received field-strength on wanted and adjacent channels,
- antenna directivity at transmitter and receiver.

RECOMMENDATION 340 *

FADING ALLOWANCES FOR THE VARIOUS CLASSES OF EMISSION

(Question 1/III, Study Programme 1A/III)

The C.C.I.R., (1951 – 1953 – 1956 – 1963

CONSIDERING

(a) that Table I to Recommendation 339-1 is a provisional and partial reply to Question 1/III, applying to stable conditions;

(b) that there is a need for figures which take into account fading and fluctuations in field intensity;

(c) that it is not yet possible to give a full answer to Study Programme 1A/III;

(d) that, however, the information contained in Reports 248-1 and 266-1 give some results from which provisional data on fading allowances can be derived;

UNANIMOUSLY RECOMMENDS

1. that the studies in connection with Recommendation 339-1 and Study Programme 1A/III should be continued, in conjunction with those of Study Programme 16A/VI for the purpose of determining whether the provisional values given in the Annex may be accepted or should be modified;

2. that meanwhile, the values given in the Annex may be regarded as provisional total fading allowances (combined fading safety-factors and intensity fluctuation-factors);

3. that meanwhile, these values may be used as a guide, in conjunction with the values for signal-to-noise ratios required for stable conditions given in Recommendation 339-1, Table I to estimate monthly-median values of hourly-median field intensity, necessary for the various types and grade of service: similarly, the fading allowances may be used as a guide, in conjunction with the values for signal-to-interference ratios (for stable conditions), appropriate to the various services.

* This Recommendation replaces Recommendation 164.

ANNEX

Provisional total fading allowances[1]

Class of emission[2]		For the protection of a fading signal against : atmospheric noise subject to day-to-day intensity fluctuation (subtract 4 dB for protection against steady noise or steady interfering signal) (see Note 1)	interfering signal subject to fading and day-to-day intensity fluctuation (see Note 2)
		dB relative to ratios of monthly median values of hourly-median field-strength	
A1 telegraphy			
8 baud, low grade	(Note 3)	21	17
24 baud	(Note 4)	25	20
120 baud recorder	(Note 6)	25	20
50 baud printer	(Notes 5, 6)	32	27
A2 telegraphy			
8 baud, low grade	(Notes 3, 7)	17	13
24 baud	(Notes 4, 7)	20	17
F1 telegraphy			
120 baud recorder	(Note 6)	25	20
50 baud printer	(Notes 5, 6)	32	27
automatic repetition printer (ARQ)	(Notes 6, 8)	17	12
F4 phototelegraphy			
sub-carrier frequency-modulation single-sideband emission		23	20
Hellschreiber frequency-shift	(Note 9)	23	20
A3 telephony			
DSB just usable quality, operator to operator	(Note 10)	17	11
DSB marginally commercial	(Note 11)	19	14
DSB good commercial quality	(Note 12)	21	17
SSB and ISB: 1 channel, 2 channels, 3 channels, 4 channels	(Note 12)	21	17

(1) Combined fading safety factor and intensity fluctuation allowances.
(2) From Recommendation 339-1, Table I.

Note 1. – The allowance for day-to-day fluctuation (intensity fluctuation factor) for the signal, against steady noise, is 10 dB, estimated to give protection for 90% of the days. The fluctuations in intensity of atmospheric noise are also taken to be 10 dB for 90% of the days. Assuming that there is no correlation between the fluctuations in intensity of the noise and those of the signal (the worst condition likely to exist), a good estimate of the combined signal and noise factor is:

$$\sqrt{10^2 + 10^2} = 14 \text{ dB}$$

The combined fading allowance in Column 1 is obtained by adding 14 dB to the fading safety factor applied to each type of service. Subtraction of 4 dB reduces the intensity fluctuation allowance to 10 dB, which is the value for the signal alone; the net allowance would then be appropriate for the protection of a fading signal against steady (non-fluctuating) noise or a steady (non-fading or fluctuating) interfering signal.

Note 2. – The probability distribution of the ratio of two signals fading independently has been applied in accordance with Doc. 443 (U.S.A.), London, 1953. The combined intensity fluctuation allowance for two signals has been taken as 7 dB, which represents a compromise between the 0 dB allowance, appropriate to perfectly correlated intensity fluctuations of the two signals, and the 14 dB allowance, appropriate to uncorrelated intensity fluctuations of the two signals (see Note 1).

General Note. – Use of the recommended values only permits an estimate to be obtained, which may have to be adjusted for radio circuits of different lengths, depending on the quality of transmission required. In calculating the fading safety factor for rapid or short-period fading, a log-normal amplitude distribution of the received fading signal has been used (using 7 dB for the ratio of median level to level exceeded for 10 % or 90% of the time) except for high-speed automatic telegraphy services, where the protection has been calculated on the assumption of a Rayleigh distribution. The following notes refer to protection against rapid or short-period fading.

Note 3. – For protection 90% of the time.

Note 4. – For protection 98% of the time.

Note 5. – For protection 99·99% of the time.

Note 6. – Minimum of 2-element diversity assumed.

Note 7. – Total sideband power, combined with keyed carrier, is assumed to give partial (two-element) diversity effect. An allowance of 4 dB is made for 90% protection (8 baud), and 6 dB for 98% protection.

Note 8. – Based on 90% traffic efficiency.

Note 9. – Based on 95% protection.

Note 10. – Based on 70% protection.

Note 11. – Based on 80% protection.

Note 12. – Based on 90% protection.

RECOMMENDATION 341 *

THE CONCEPT OF TRANSMISSION LOSS IN STUDIES OF RADIO SYSTEMS

(Question 1/III, Study Programme 1A/III)

The C.C.I.R., (1959)

CONSIDERING

(a) that the radio-frequency signal power, p_a, available ** at the terminals of a receiving antenna for a given power input, p_t, to the terminals of a transmitting antenna, provides a measure which is useful in determining, at the terminals of the receiving antenna, the service from, or the interference produced by, a radio system involving a transmitting antenna, a receiving antenna, and the intervening propagation medium;

(b) that the ratio, p_t/p_a, which will be called the system loss, is a convenient dimensionless form for expressing this measure of the combined radio propagation and circuit loss characteristics of such a system;

(c) that the available power, at the terminals of the receiving antenna, is sometimes a simpler and more directly useful concept than that of the effective field-strength, especially where the effective field is the resultant of a large number of received field components, corresponding to several modes of propagation, arriving at the receiving antenna at different angles and possibly with different polarizations;

(d) that the relationship between the system loss and the conditions in the neighbourhood of the receiving antenna, does not depend solely on the received field-strength, because the impedance of the antenna depends itself upon the conditions in its neighbourhood;

(e) that the power, P_t', radiated from the transmitting antenna, required for satisfactory reception in the presence of noise, is precisely determined for a system with transmission loss, L, by the simple relation: $P_t' = L + P$; P is the minimum signal power that is required to provide satisfactory reception (as defined in Report 322), available from an equivalent lossless receiving antenna;

(f) that it is desirable to standardize terminology and notation for describing system loss and its various components;

UNANIMOUSLY RECOMMENDS

that the terminology and notation given in the Annex should be adopted for use by the C.C.I.R., in accordance with the further discussion of the use of these terms given in Report 112.

ANNEX

1. System loss *(L_s)*.

The system loss of a radio circuit, consisting of a transmitting antenna, a receiving antenna and the intervening propagation medium, is defined as the ratio, p_t/p_a, where p_t is the radio-frequency power input to the terminals of the transmitting antenna and p_a is the resultant radio-

* This Recommendation replaces Recommendation 241.

** The available power, p_a, is the power which would go to the load if it were matched to the antenna impedance.

frequency signal-power available at the terminals of the receiving antenna. Both p_t and p_a are expressed in watts. The system loss is usually expressed in decibels: *

$$L_s = 10 \log_{10} (p_t/p_a) = P_t - P_a$$

Note that the system loss, as defined above, excludes any transmitting or receiving antenna transmission line losses, since it is considered that such losses are readily measurable. On the other hand, the system loss includes all of the losses in the transmitting and receiving antenna circuits, including, not only the transmission loss due to radiation from the transmitting antenna and re-radiation from the receiving antenna, but also any ground losses, dielectric losses, antenna loading coil losses, terminating resistor losses in rhombic antennae, etc. The inclusion of all of the antenna circuit losses in the definition of system loss provides a quantity which can always be accurately measured and which is directly applicable to the solution of radio system problems.

2. Transmission loss *(L)*.

The transmission loss of a radio circuit, consisting of a transmitting antenna, a receiving antenna, and the intervening propagation medium, is defined as the dimensionless ratio, p_t'/p_a', where p_t' is the radio-frequency power radiated from the transmitting antenna, and p_a' is the resultant radio-frequency signal power which would be available from the receiving antenna, if there were no circuit losses other than those associated with its radiation resistance. The transmission loss is usually expressed in decibels:

$$L = 10 \log_{10} (p_t'/p_a') = L_s - L_{tc} - L_{rc}$$

where L_{tc} and L_{rc} are the losses, expressed in decibels, in the transmitting and receiving antennae circuits respectively, excluding the losses associated with the antennae radiation resistances; i.e., the definitions of L_{tc} and L_{rc} are 10 $\log_{10} (r'/r)$, where r' is the resistive component of the antenna circuit and r is the radiation resistance.

3. Basic transmission loss *(L_b)*.

The basic transmission loss (sometimes called path loss), of a radio circuit, is the transmission loss expected between ideal, loss-free, isotropic, transmitting and receiving antennae at the same locations as the actual transmitting and receiving antennae.

4. Path antenna gain *(G_p)*

The path antenna gain is equal to the change in the transmission loss when lossless, isotropic antennae are used at the same locations as the actual antennae:

$$G_p = L_b - L$$

5. Path antenna power gain *(G_{pp})*

The path antenna power gain is equal to the increase in the system loss when lossless, isotropic, antennae are used at the same locations as the actual antennae:

$$G_{pp} = L_b - L_s = G_p - L_{tc} - L_{rc}$$

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

Note that G_{pp} will be negative when the antenna circuit losses exceed the path antenna gain.

In some idealized situations, the path antenna power gain, G_{pp}, is simply the sum $(G_{tp} + G_{rp})$ of the free space power gains, G_{tp} and G_{rp}, of the transmitting and receiving antennae relative to lossless, isotropic antennae. However, in most practical situations, G_{pp} is less than $(G_{tp} + G_{rp})$, because of the complex nature of the received field. The path antenna power gain may be measured, by determining the increase in the system loss when both the transmitting and receiving antennae are replaced *simultaneously*, by simple standard antennae such as short electric or magnetic dipoles, and then adding the calculated path antenna power gain corresponding to the use of the standard antennae. For ionospheric or tropospheric scatter propagation, the path antenna power gain is sometimes substantially smaller than the sum of the free space power gain $(G_{tp} + G_{rp})$; in such cases, the path antenna power gain cannot be defined by the sum of the effective power gains of the transmitting and receiving antennae (as determined by replacing first one antenna and then the other successively by a standard antenna), since such effective power gains depend upon the gain of the antenna used at the other terminal.

For ionospheric or tropospheric propagation, the transmission loss L, the basic transmission loss L_b, and the path antenna gain G_p, are all random variables with respect to time, and tend to be normally distributed about their expected values. Typically, L and G_p are negatively correlated with each other, and thus the variance of L_b is usually substantially less than the sum of the variances of L and of G_p; for this reason it will often be more practical simply to measure the system loss with the particular antennae intended for use, rather than attempt to calculate the expected system loss and its variance with time, in terms of the measured or calculated values of the basic transmission loss, the path antenna gain, and the losses L_{tc} and L_{rc}.

Note also that the path antenna gain may actually be negative. For example, the path antenna gain will usually be negative for ground wave or tropospheric wave propagation between a vertically polarized and a horizontally polarized antenna, and the concept of path antenna gain should prove to be useful for expressing the results of such cross-polarization measurements.

6. Propagation loss *(L_p)*

The propagation loss is the system loss expected if the antennae gains and circuit resistances were the same as if the antennae were located in free space:

$$L_p = L_s - L_t - L_r$$

L_t and L_r are defined by 10 $\log_{10} (r'/r_f)$ where r' is the actual antenna resistance and r_f is the resistance the antenna would have if it were in free space and there were no losses other than radiation losses.

RECOMMENDATION 342-1

AUTOMATIC ERROR CORRECTING SYSTEM FOR TELEGRAPH SIGNALS TRANSMITTED OVER RADIO CIRCUITS

(Study Programme 5A/III)

The C.C.I.R., (1951 – 1953 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that it is essential to be able to interconnect terminal start-stop apparatus employing the International Telegraph Alphabet No. 2 by means of radiotelegraph circuits;

(b) that radiotelegraph circuits are required to operate under varying conditions of radio propagation, atmospheric noise and interference, which introduce varying degrees of distortion which may at times exceed the margin of the receiving apparatus;

(c) that, in consequence, the transmission of 5-unit code signals over radio circuits is liable to errors and that such errors are not automatically detectable by the receiving apparatus;

(d) that an effective means of reducing the number of wrongly printed characters is the use of codes, permitting the correction of errors by detecting the errors and automatically causing repetition;

(e) that the method using synchronous transmission and automatic repetition (ARQ), is now well proven;

(f) that it is desirable to permit the correct phase to be established automatically on setting up a circuit;

(g) that certain circumstances can occur which may result in a loss of the correct phase relationship between a received signal and the receiving apparatus;

(h) that it is desirable to permit the correct phase relationship to be re-established automatically after such a loss, without causing errors;

(i) that, to avoid mis-routing traffic, it is essential to prevent phasing to a signal which has been unintentionally inverted;

(j) that there is sometimes a need to subdivide one or more channels, to provide a number of sub-channels at a proportionately reduced character rate;

(k) that the method of automatically achieving the correct phase relationship between the received signal and the sub-channelling apparatus should be an integral part of the phasing process;

(l) that compatibility with existing equipment, designed in accordance with Recommendation 242, Los Angeles, 1959, is a requirement;

UNANIMOUSLY RECOMMENDS

1. that, when the direct use of a 5-unit code on a radio circuit gives an intolerable error rate and there is a return circuit, a 7-unit ARQ system be employed;

2. when automatic phasing of such a system is required, the 7-unit system, described in Annex I, should be adopted as a preferred system;

3. that equipment, designed in accordance with § 2, should be provided with switching, to permit operation with equipment designed in accordance with Recommendation 242, Los Angeles, 1959.

Note. – Methods in accordance with this Recommendation are described in Doc. III/17, Geneva, 1962.

ANNEX I

1. Table of conversion

TABLE I

Table of code conversion

	International code No. 2	7-unit code
A	ZZAAA	AAZZAZA
B	ZAAZZ	AAZZAAZ
C	AZZZA	ZAAZZAA
D	ZAAZA	AAZZZAA
E	ZAAAA	AZZZAAA
F	ZAZZA	AAZAAZZ
G	AZAZZ	ZZAAAAZ
H	AAZAZ	ZAZAAZA
I	AZZAA	ZZZAAAA
J	ZZAZA	AZAAAZZ
K	ZZZZA	AAAZAZZ
L	AZAAZ	ZZAAAZA
M	AAZZZ	ZAZAAAZ
N	AAZZA	ZAZAZAA
O	AAAZZ	ZAAAZZA
P	AZZAZ	ZAAZAZA
Q	ZZZAZ	AAAZZAZ
R	AZAZA	ZZAAZAA
S	ZAZAA	AZAZAZA
T	AAAAZ	ZAAAZAZ
U	ZZZAA	AZZAAZA
V	AZZZZ	ZAAZAAZ
W	ZZAAZ	AZAAZAZ
X	ZAZZZ	AAZAZZA
Y	ZAZAZ	AAZAZAZ
Z	ZAAAZ	AZZAAAZ
Carriage return	AAAZA	ZAAAAZZ
Line feed	AZAAA	ZAZZAAA
Figures	ZZAZZ	AZAAZZA
Letters	ZZZZZ	AAAZZZA
Space	AAZAA	ZZAZAAA
Unperforated tape	AAAAA	AAAAZZZ
Signal repetition		AZZAZAA
Signal α		AZAZAAZ
Signal β		AZAZZAA

2. Repetition cycles

2.1 Four characters for normal circuits, which are not subject to excessive propagation time. The cycle should comprise one “ signal repetition ” and three stored characters.

2.2 Eight characters on circuits for which the four-character repetition cycle is inadequate. The cycle should comprise one “ signal repetition ”, three signals β and four stored characters, or one “ signal repetition ” and seven stored characters.

3. Channel arrangement

3.1 *Channel A*

3.1.1 For equipment employing a 4-character repetition cycle: one character inverted followed by three characters erect. (See Fig. 1*a*).

3.1.2 For equipment employing an 8-character repetition cycle: one character inverted followed by seven characters erect. (See Fig. 2*a*).

3.2 *Channel B*

3.2.1 For equipment employing a 4-character repetition cycle: one character erect followed by three characters inverted. (See Fig. 1*b*).

3.2.2 For equipment employing an 8-character repetition cycle: one character erect followed by seven characters inverted. (See Fig. 2*b*).

3.3 *Channel C*

As for Channel B (See Figs. 1*c* and 2*c*).

3.4 *Channel D*

As for Channel A (See Figs. 1*d* and 2*d*).

3.5 *Order of transmission*

3.5.1 Characters of Channels A and B are transmitted consecutively. (See Figs. 1*e* and 2*e*)

3.5.2 Elements of Channel C are interleaved with those of Channel A. (See Figs. 1*g* and 2*g*).

3.5.3 Elements of Channel D are interleaved with those of Channel B. (See Figs. 1*g* and 2*g*).

3.5.4 In the aggregate signal, A elements precede those of C, and B elements precede those of D. (See Figs. 1*g* and 2*g*).

3.5.5 The first erect character on A, transmitted after the inverted character on A, is followed by the erect character on B. (See Figs. 1*e* and 2*e*).

3.5.6 The erect character on C is followed by the inverted character on D. (See Figs. 1*f* and 2*f*).

3.5.7 The inverted character on A is element-interleaved with the erect character on C. (See Figs. 1*g* and 2*g*).

4. Sub-channel arrangement

4.1 The character transmission rate of the fundamental sub-channel should be a quarter of the standard character rate.

4.2 Sub-channels should be numbered 1, 2, 3 and 4 consecutively.

4.3 Where a 4-character repetition cycle is used, sub-channel 1 should be that sub-channel which has opposite keying polarity to the other three sub-channels of the same main channel. (See Fig. 3*a-d*).

Where an 8-character repetition cycle is used, sub-channel 1 should be that sub-channel which has alternately erect and inverted keying polarity. (See Fig. 3*e-h*).

4.4 When sub-channels of half-character rate, or three-quarter-character rate are required, combinations of the fundamental sub-channels should be arranged as shown in Table II.

TABLE II

Proportion of full-channel character rate	Combination of fundamental sub-channels
(1) quarter (2) quarter (3) half	No. 1 No. 3 Nos. 2 and 4
(1) half (2) half	Nos. 1 and 3 Nos. 2 and 4
(1) quarter (2) three-quarters	No. 1 Nos. 2, 3 and 4

5. Diagrams

As a result of the characteristics specified in §§ 2, 3 and 4 of this Annex, the transmission of characters will be as shown in Figs. 1, 2 and 3.

6. Automatic phasing

6.1 Automatic phasing should normally be used. It should be initiated either:

6.1.1 after a waiting period during which cycling due to the receipt of errors has occurred continuously on both channels of a 2-channel system, or on at least two main channels of a 4-channel system;

6.1.2 after equal counts of A and Z elements have been made over at least two consecutive system cycles whilst continuous cycling due to the receipt of errors is occurring on all main channels;

6.2 when the slave station is phasing, it should transmit in each channel, in place of the " signal repetition ", a 7-element signal in which all 7 elements are of the same polarity, all other characters in the repetition cycle being transmitted unchanged; *

7. C.C.I.T.T. Recommendation S.12 recommends, that the interval between the beginning of successive start elements of the signals transmitted into the landline network be 145 5/6 ms. Therefore, the duration of the transmission cycle on the radio circuit and also the modulation rate must be chosen correspondingly, if connection to the network is required.

Practical values for the modulation rate in bauds and the duration of the transmission cycle, which enable synchronization to be effected by using a single oscillator for three cases, are shown in Table III.

TABLE III

Transmission cycle (ms)	Modulation rate (bauds)	
	2-channel operation	4-channel operation
145 5/6	96	192
This is the preferred standard. See C.C.I.T.T. Recommendations S.12 and S.13		
163 1/3 140	85 5/7 100	171 3/7 200

The transmission cycle of 145 5/6 ms is the preferred standard for connection to 50-baud networks.

The transmission cycle of 163 1/3 ms is suitable for connecting to 45-bauds networks.

The transmission cycle of 140 ms is suitable for radio circuits without direct connection to a landline network.

The tolerance on the frequency of the master oscillator, controlling the timing of each terminal equipment, should be $\pm 1 \times 10^{-6}$.

8. C.C.I.T.T. Recommendation U.20 gives the signalling conditions to be used when telex communication is to be established by means of such radio circuits.

* Existing systems without this facility need not be modified because compatibility is assured.

8.1 for circuits on switched telegraph networks, the conditions of C.C.I.T.T. Recommendation U.20 should apply;

8.2 for point-to-point circuits, Administrations may adopt, at the terminal equipment under their jurisdiction, their own method of stopping and starting the motors of the receiving machines, based on C.C.I.T.T. Recommendation S.7;

8.3 signal β should normally be transmitted to indicate the idle circuit condition. However, for signalling purposes, the signals α and β may be employed.

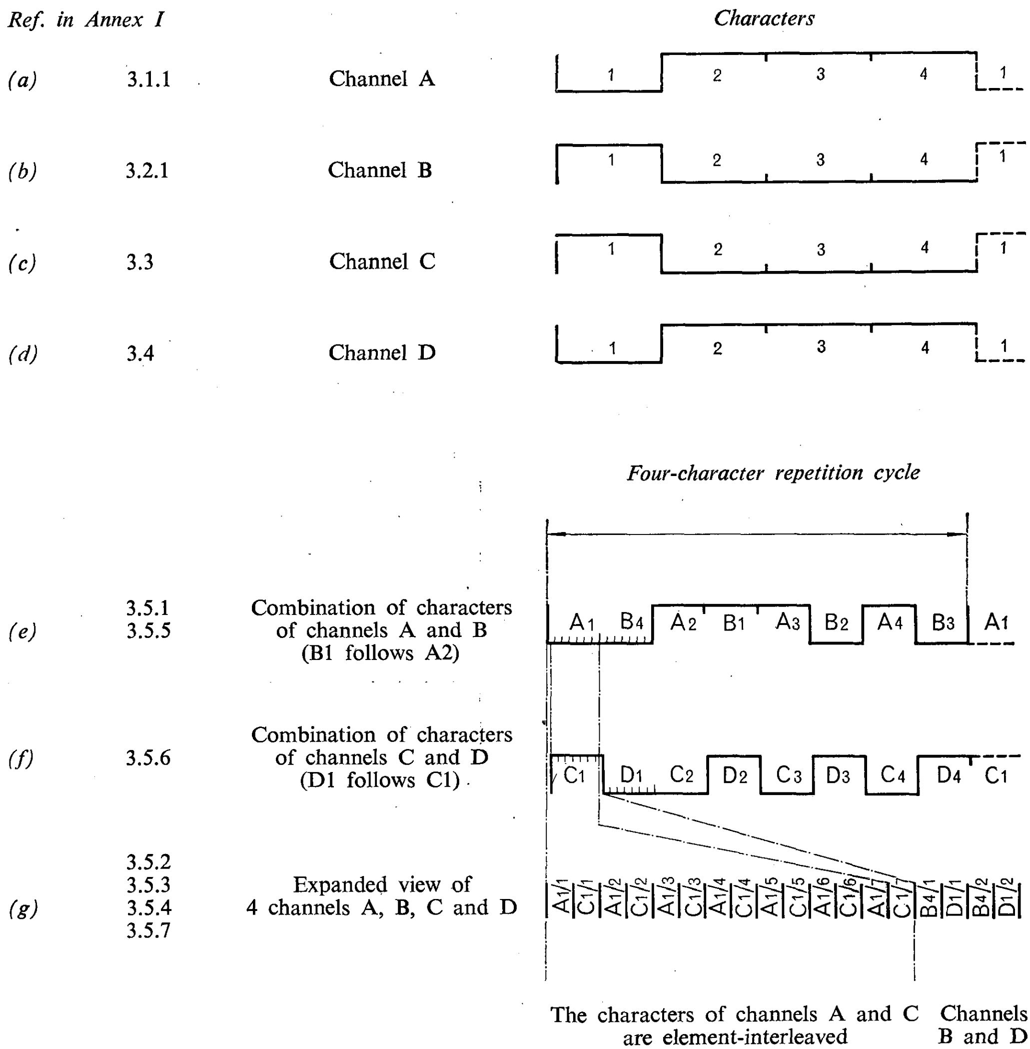


FIGURE 1

Channel arrangement for a four-character repetition cycle

Ref. in Annex I		
(a)	3.1.2	Channel A
(b)	3.2.2	Channel B
(c)	3.3	Channel C
(d)	3.4	Channel D
(e)	3.5.1 3.5.5	Combination of characters of channels A and B (B1 follows A2)
(f)	3.5.6	Combination of characters of channels C and D (D1 follows C1)
(g)	3.5.2 3.5.3 3.5.4 3.5.7	Expanded view of 4 channels A, B, C and D

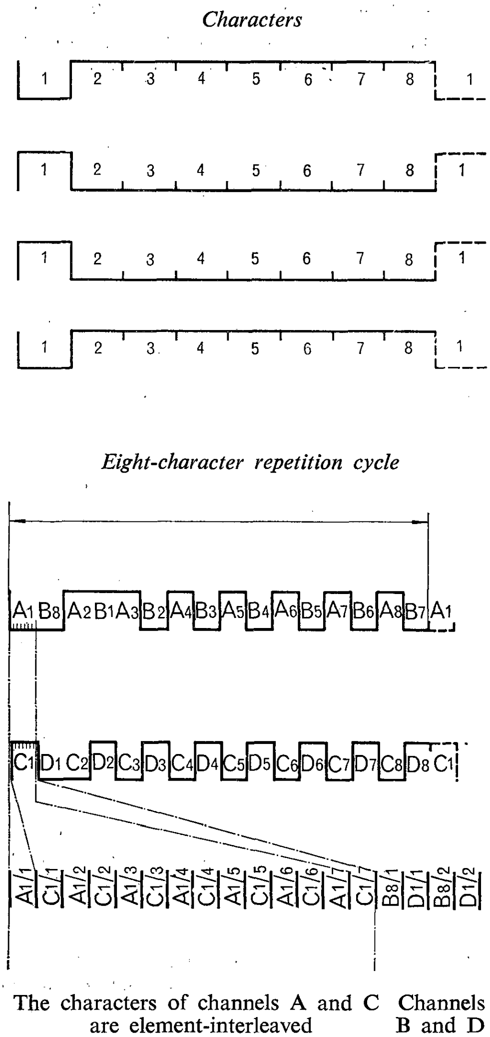


FIGURE 2

Channel arrangement for an eight-character repetition cycle

Ref. in Annex I

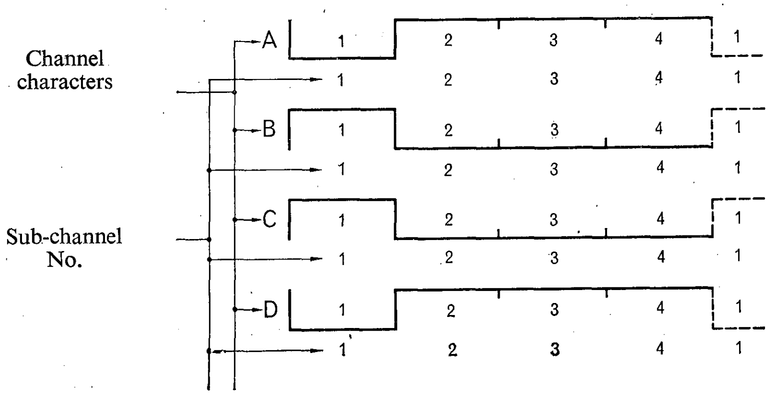
(a) 3.1.1, 4.2, 4.3

(b) 3.2.1, 4.2, 4.3

(c) 3.3, 4.2, 4.3

(d) 3.4, 4.2, 4.3

Four-character repetition cycle



(e) 3.1.2, 4.2, 4.3

(f) 3.2.2, 4.2, 4.3

(g) 3.3, 4.2, 4.3

(h) 3.4, 4.2, 4.3

Eight-character repetition cycle

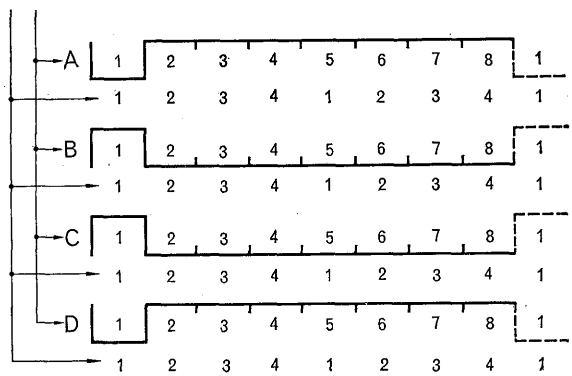


FIGURE 3

Sub-channelling arrangements for a four and an eight-character repetition cycle

ANNEX II

Terms related to ARQ-Systems *

Part 1

1. Signal repetition / RQ-signal / Signal Roman one – the seven unit combination (AZZAZAA) which is used to request a repetition (RQ-signal) or to precede a re-transmission (BQ-signal);

2. Repetition cycle – the sequence of characters, the number of which is determined by the *loop time-delay of the system*, to provide automatic repetition of information;

3. RQ-cycle / Request cycle – the *repetition cycle* transmitted by ARQ-apparatus at the detection of a mutilation;

4. BQ-cycle / Response cycle – the *repetition cycle* transmitted by ARQ-apparatus at a request for repetition;

5. Non-print cycle – the interval at the ARQ-receiver, initiated by the detection of a mutilation or a *signal repetition*, that has the same duration as a *repetition cycle* and during which all signals received are prevented from being printed;

6. Gated RQ – a procedure in which a check is made for the presence of a *signal repetition* during a non-print cycle;

7. Tested RQ – a procedure in which a check is made for the presence of a *signal repetition* and a check is made for the ratio A/Z on all characters received after the *signal repetition* within the *non-print cycle*;

8. Tested repetition cycle – a *non-print cycle* in which a check is made for the presence of a *signal repetition* and for the correct ratio A/Z of all the characters received;

9. Cycling – the condition that a repetition procedure is in progress;

10. Marking pattern – a specific pattern of polarity inversions applied to characters in an *aggregate signal*;

11. Marked cycle / System cycle – a cycle consisting of a specific character *marking pattern*, that is continuously repeated and has the duration of a *repetition cycle*;

12. System phase / Marked cycle phase – the condition in which the *marking pattern* of the local timing coincides with the *marked cycle* of the received signal;

13. Phasing / Phase hunting – the condition in which a station is hunting for *character phase* or *system phase*;

14. Manual phasing – *phasing* by manual action only;

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* The twenty-three terms and definitions in Part 1 of this list have been studied by a joint Working Party of Study Groups III and XIV during the Xth Plenary Assembly of the C.C.I.R. Geneva, 1963, as a provisional contribution (see § 2 of the Annex to Resolution 21-1) to the " List of Definitions of Essential Telecommunication Terms " (Volume II to be published later).
The other terms and definitions contained in Part 2 of this list, which are of more general application, are given as information pending examination by the C.C.I.T.T.

15. Semi-automatic phasing – *phasing* completed automatically after manual initiation;

16. Automatic phasing – *phasing*, initiated and completed automatically after automatic detection of " out-of-phase ";

17. Master station – the station, the transmitting equipment of which is directly driven by a master oscillator but the receiver timing of which is normally synchronized to the incoming signal;

18. Slave station – the station, the receiver and transmitter timing of which are both synchronized to the received signal;

19. End-to-end time delay – the delay between the output terminals of an ARQ-transmitter and the input terminals of the ARQ-receiver at the other end (this is the sum of radio and line circuit delays in one direction of a route);

20. Loop time-delay of a route – the sum of the end-to-end time delays in the send and return directions of a route;

21. Master station delay – the period between the beginning of reception of a *signal repetition* at the ARQ-input terminals at the *master station* and the beginning of transmission of the replying *signal repetition* at that station.

Note. – This comprises the " scanning " and equipment delays and a further delay which, when added to the *loop time delay of the system*, produces an integral multiple of the *character cycle* duration;

22. Slave station delay – the period between the beginning of reception of a *signal repetition* at the ARQ-input terminals at the *slave station* and the beginning of transmission of the replying *signal repetition* at that station.

Note. – This comprises " scanning " and equipment delays and a " pre-set " delay between the receiver and the transmitter;

23. Loop time-delay of a system (as seen from the master station) – the sum of the *loop time-delay of the route* and the *slave station delay*, measured under working conditions.

Part 2

(a) Aggregate signal – the synchronous signal produced by combining the channel signals;

(b) Balanced aggregate signal – an aggregate signal containing equal numbers of elements of each polarity;

(c) Character cycle – the period in which each channel of a time-division multiplex transmission has completed one character in the synchronous path;

(d) Element synchronism – in synchronous systems:
the condition in which an element of the local timing coincides completely with an element of the received signal;

(e) Synchronizing	– the action of adjustment of element synchronism;
(f) Phase relationship	– in synchronous systems: the relative phase of receiving apparatus and incoming signals, or receiving and sending apparatus;
(g) Character phase	– the condition in which a character cycle of the local timing coincides completely with a character cycle of the received signal. *Note*. – Under these conditions, a character of the aggregate signal transmitted on a particular channel is received on the correct channel.
(h) Sub-channel	– a teleprinter channel which is allocated a quarter rate of a normal channel, or multiples thereof;
(j) Sub-channel phase	– the condition in which a character transmitted on a particular sub-channel is received on the correct sub-channel;
(k) Transposition	– Add to definition 33.25 of the I.T.U. " List of definitions . . " (Part I): " Transpositions may be regarded as of first or higher order according to the number of interchanges occurring within a character."

RECOMMENDATION 343-1

FACSIMILE TRANSMISSION OF METEOROLOGICAL CHARTS OVER RADIO CIRCUITS

(Question 232)

The C.C.I.R., (1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that increasing use is being made of facsimile telegraphy for the transmission of meteorological charts for reception on direct-recording apparatus;

(b) that it is desirable to standardize certain characteristics of the radio circuits for this purpose;

UNANIMOUSLY RECOMMENDS

1. that, when frequency modulation of the sub-carrier is employed for the facsimile transmission of meteorological charts over radio circuits, the following characteristics should be used:

centre frequency	1900 Hz
frequency corresponding to black	1500 Hz
frequency corresponding to white	2300 Hz;

2. that, when direct frequency modulation is employed on radio circuits, the following characteristics should be used:

2.1 *HF (decametric) circuits*

centre frequency (corresponding to the assigned frequency)	f_o,
frequency corresponding to black	$f_o - 400$ Hz,
frequency corresponding to white	$f_o + 400$ Hz;

2.2 *LF (kilometric) circuits*

centre frequency (corresponding to the assigned frequency)	f_o,
frequency corresponding to black	$f_o - 150$ Hz,
frequency corresponding to white	$f_o + 150$ Hz;

3. that this Recommendation should be considered as an answer to Question 232, the study of which is hereby terminated.

RECOMMENDATION 344-1

STANDARDIZATION OF PHOTOTELEGRAPH SYSTEMS FOR USE ON COMBINED RADIO AND METALLIC CIRCUITS

The C.C.I.R., *(1948 – 1953 – 1956 – 1959 – 1963 – 1966)*

CONSIDERING

(a) that to facilitate interworking, it is desirable to standardize the characteristics of systems employed for phototelegraph transmission over long-distance HF (decametric) circuits;

(b) that it is desirable to standardize certain characteristics of these systems in such a way as to make them equally suitable for transmission over metallic circuits;

(c) that the transmission system using direct amplitude-modulation is generally unsatisfactory over HF (decametric) radio circuits, because of the intolerable fading ratio usually encountered;

(d) that the system of sub-carrier frequency-modulation has proved satisfactory, but requires standardization in respect of the centre frequency and shift frequencies, taking into account the values of the picture-modulation frequencies to be transmitted;

(e) that, when a direct frequency-modulation system is employed, the terminal equipment normally used for a sub-carrier modulation system should be usable without serious modifications;

(f) that, taking into account the degree of distortion that is tolerable, the effect of multipath echoes on long-distance HF (decametric) radio circuits normally limits the maximum admissible picture-modulation frequency to approximately 600 Hz;

(g) that Recommendations M.88, T.1, T.10, T.11, T.12, T.15 and T.20 of the C.C.I.T.T. give standards for phototelegraph systems;

UNANIMOUSLY RECOMMENDS

1. that over the radio path,

1.1 the preferred method of transmission of half-tone pictures is by sub-carrier frequency-modulation, of a single-sideband or independent-sideband emission with reduced carrier. The following characteristics should therefore be used:

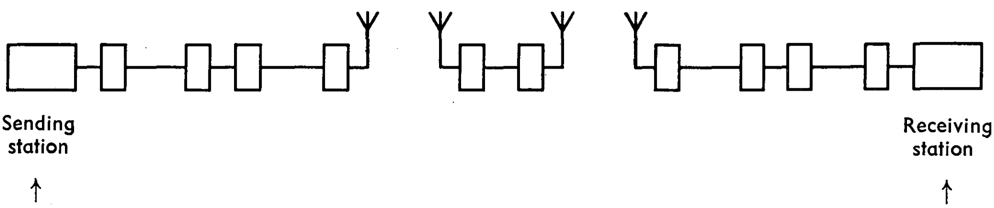
centre frequency	1900 Hz,
frequency corresponding to white	1500 Hz,
frequency corresponding to black	2300 Hz;

(The 1500 Hz frequency is also used for the phase-synchronizing frequency)

1.2 when a direct frequency-modulation system is employed, the following characteristics should be used:

centre frequency (corresponding to the assigned frequency)	f_o,
frequency corresponding to white	$f_o - 400$ Hz,
frequency corresponding to black	$f_o + 400$ Hz;

1.3 that the frequency tolerances on each of the various sections of a combined radio and metallic circuit should be no greater than those proposed by the C.C.I.T.T. (see Annex V to Doc. III/3, 1963-1966) as shown in Fig. 1, which gives the composition of a very long circuit of this type.



Frequency tolerances (Hz) for short-term (1 s)

8	2	2	8	8	2	2	8

Frequeucy tolerances (Hz) for long-term (15 min)

16	2	2	16	16	2	2	16

FIGURE 1

If it is assumed that these deviations are allocated at random and if we take the standard deviations, we obtain 15 and 28 Hz respectively;

2. that, for the present, the following alternative characteristics should be used:

	a	*b*	
index of cooperation	352	264	
speed of rotation of drum in r.p.m.	60	90/45	(The speed of 45 r.p.m. is for use when the radio propagation conditions demand it);

In due course, characteristic *b* will become obsolete.

3. that frequency-modulation or amplitude-modulation may be used in the metallic portions of the combined circuit. When conversion from amplitude-modulation to frequency-modulation (or vice versa) is required, the conversion should be such that the deviation of the frequency-modulated carrier varies linearly with the amplitude of the amplitude-modulated carrier.

The standards for both amplitude-modulated and frequency-modulated transmissions will be found in C.C.I.T.T. Recommendations T.1, T.11 and T.15.

Each Administration will decide, when the question arises, on the location of modulation converters. They may be placed either at the terminal phototelegraph station or at the control station associated with the radio station, to facilitate speech on the circuit used for phototelegraphy, if the radio channel will carry speech.

Note. – The provisions of § 2 do not imply the imposition of such standards on private users who use their own equipment for the transmission of pictures over private circuits.

RECOMMENDATION 345 *

TELEGRAPH DISTORTION

The C.C.I.R., (1953 – 1956 – 1959 – 1963)

CONSIDERING

that the definitions applying to telegraph distortion and to the mutilation of telegraphic signals, which appear in Section 33, Part I, of the List of Definitions of Essential Telecommunication Terms, published by the International Telecommunication Union, give an answer to Question 18, which required a general definition of telegraph distortion capable of being usefully applied to the cause of radiotelegraphy;

UNANIMOUSLY RECOMMENDS

that the following definitions, contained in Section 33 of the above-mentioned List of Definitions of Essential Telecommunication Terms, should be applied to radiotelegraphy:

Perfect modulation (or restitution) (Definition 33.01 of the List)

Modulation (or restitution) such, that all the significant intervals are associated with correct significant conditions and conform accurately to their theoretical durations.

Incorrect modulation (or restitution)
Defective modulation (or restitution) } (Definition 33.03 of the List)

Modulation (or restitution) containing one or more elements, the significant condition of which differs from that corresponding to the kind prescribed by the code.

Telegraph distortion (of a modulation or a restitution) (Definition 33.04 of the List)

(a) A modulation (or restitution) suffers from telegraph distortion, when the significant intervals have not all exactly their theoretical durations.

(b) A modulation (or restitution) is affected by telegraph distortion, when significant instants do not coincide with the corresponding theoretical instants.

* This Recommendation replaces Recommendation 245.

Transmitter distortion (Definition 33.059 of the 1st Supplement to the List)

A signal transmitted by an apparatus (or a signal at the output of a local line with its termination), is affected by telegraph distortion, when the significant intervals of this signal have not exactly their theoretical durations.

Degree of individual distortion of a particular significant instant (of a modulation or of a restitution) (Definition 33.06 of the List)

Ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant.

This displacement is considered positive when the significant instant occurs after the ideal instant.

The degree of individual distortion is usually expressed as a percentage.

Degree of isochronous distortion (Definition 33.07 of the 1st Supplement to the List)

(a) Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating any two significant instants of modulation (or of restitution), these instants being not necessarily consecutive.

(b) Algebraical difference between the highest and lowest value of individual distortion affecting the significant instants of an isochronous modulation. (The difference is independent of the choice of the reference ideal instant.)

The degree of distortion (of an isochronous modulation or restitution), is usually expressed as a percentage.

Note. – The result of the measurement should be completed by an indication of the period, usually limited, of the observation.

For a prolonged modulation (or restitution), it will be appropriate to consider the probability that an assigned value of the degree of distortion will be exceeded.

Degree of start-stop distortion (Definition 33.08 of the 1st Supplement to the List)

(a) Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and theoretical intervals separating any significant instant of modulation (or of restitution) from the significant instant of the start element immediately preceding it.

(b) The highest absolute value of individual distortion affecting the significant instants of a start-stop modulation.

The degree of distortion of a start-stop modulation (or restitution) is usually expressed as a percentage.

Note 1. – See Note to Definition 33.07.

Note 2. – Distinction can be made between the degree of *late* (or positive distortion and the degree of *early* (or negative) distortion.

Degree of gross start-stop distortion (Definition 33.09 of the List)

Degree of distortion determined when the unit interval and the theoretical intervals assumed are exactly those appropriate to the standardized modulation rate.

Note. – See Note to Definition 33.07.

Degree of synchronous start-strop distortion (i.e. at the actual mean modulation rate) (Definition 33.10 of the List)

Degree of distortion determined when the unit interval and the theoretical intervals assumed are those appropriate to the actual mean rate of modulation (or of restitution).

Note 1. – See Note to Definition 33.07.

Note 2. – For the determination of the actual mean modulation rate, account is only taken of those significant instants of modulation (or restitution), which correspond to a change of condition in the same sense as that occurring at the beginning of the start element.

Characteristic distortion (Definition 33.15 of the List)

Distortion caused by transients which, as a result of the modulation, are present in the transmission channel and depend on its transmission qualities.

Fortuitous distortion (Definition 33.16 of the List)

Distortion resulting from causes generally subject to random laws (accidental irregularities in the operation of the apparatus and of the moving parts, disturbances affecting the transmission channel, etc.).

Bias distortion, Asymmetrical distortion (Definition 33.17 of the List)

Distortion affecting a two-condition (or binary) modulation (or restitution), in which all the significant intervals corresponding to one of the two significant conditions have longer or shorter durations than the corresponding theoretical durations.

Character error rate of a telegraph communication (Definition 33.19 of the 1st Supplement to the List)

Ratio of the number of alphabetic signals of a message incorrectly received (after automatic translation, where applicable), to the number of alphabetic signals of the message, the keying being correct.

Note 1. – A telegraph communication may have a different error rate for the two directions of transmission.

Note 2. – The notion of character error rate could be applied to any operation taking place in a telegraph communication (e.g. keying, translation, etc).

Note 3. – The statement of the error rate will be accompanied by that of the time interval, generally limited, during which the observation was made. For a communication established for a sufficiently long time, the probability of exceeding an assigned value of error rate could be considered.

Note 4. – Faulty translation, resulting from a previous error in functional control (such as shift, line feed, synchronism, etc.), is not counted in calculating a character error rate; in such a case, the error in the functional control signal is alone counted and is counted only once.

Element error rate (Doc. 203, Geneva, 1963)

The ratio of the number of unit elements incorrectly received to the total number of unit elements sent.

Efficiency factor in time (of a telegraph communication with automatic repetition for the correction of errors) (Definition 33.23 of the List)

Ratio of the time necessary to transmit a text automatically without repetition, at a specified modulation rate, to the time actually taken to receive the same text with a given error rate.

Note 1. – The whole of the apparatus comprising the communication is assumed to be in the normal conditions of adjustment and operation.

Note 2. – A telegraph communication may have a different efficiency factor in time for the two directions of transmission.

Note 3. – The actual conditions in which the measurement is made should be specified, in particular the duration of the measurement.

Mutilation (Definition 33.24 of the List)

A transmission defect in which a signal element becomes changed from one significant condition to another.

Transposition (Definition 33.25 of the List) (See also Annex II, Part 2, definition *k* of Recommendation 342-1)

A transmission defect in which, during one character period, one or more signal elements are changed from one significant condition to the other, and an equal number of elements are changed in the opposite sense.

RECOMMENDATION 346 *

FOUR-FREQUENCY DIPLEX SYSTEMS

(Question 8/III)

The C.C.I.R., (1956 – 1959 – 1963)

CONSIDERING

(a) that there are in use, in the fixed radiotelegraph services operating between 2 MHz and 27 MHz, four-frequency diplex (or twinplex) systems, in which each of four frequencies is used to transmit one of the four possible combinations of signals corresponding to two telegraph channels; it being understood that either one, or both of the two telegraph channels may be sub-channelled by time-division methods and that the use of such systems may be extended;

(b) that it is desirable to standardize the main characteristics of four-frequency diplex systems;

(c) that it may sometimes be necessary to employ the same radio transmitter to work with more than one receiving station;

(d) that circuit interruptions should be reduced to a minimum, by avoiding frequent changes of the spacing between adjacent frequencies and of the correspondence between the frequencies and the significant conditions of the channels;

(e) that various technical factors influence the choice of operating characteristics in such systems, in particular:

- the economy of bandwidth and the consequent need to control the shape of the transmitted signals;
- that a relatively wide spacing between adjacent frequencies may be necessary for high telegraph speeds;
- the signal distortion due to propagation conditions;
- the instability of the characteristics of certain receiver and transmitter elements such as oscillators, filters or discriminators;

(f) that many existing four-frequency diplex systems each use one of four values of spacing between adjacent frequencies with corresponding telegraph speeds;

(g) that it is desirable to use only one coding system, the simpler the better;

UNANIMOUSLY RECOMMENDS

1. that the following preferred values should be adopted for the spacing between adjacent frequencies:

Spacing between adjacent frequencies (Hz)	Nominal telegraph speed of each channel (bauds)
1000	over 300
500(1)	200 to 300
400(1)	100 to 200
200(1)	200(2)

(1) Lower telegraph speeds may be used with these spacings at present.
(2) Synchronous operation with phase-locked channels.

* This Recommendation replaces Recommendation 247.

2. that the following coding system should be adopted: *

Frequency of emission	Channel 1		Channel 2	
	Teleprinter	Morse	Teleprinter	Morse
f_4 (highest frequency)	A	Mark	A	Mark
f_3	A	Mark	Z	Space
f_2	Z	Space	A	Mark
f_1 (lowest frequency)	Z	Space	Z	Space

where f_1, f_2, f_3, f_4 designate the frequencies of the emissions; the spacings between adjacent frequencies $(f_4 - f_3)$ $(f_3 - f_2)$ $(f_2 - f_1)$, being equal,
A represents the start signal of the teleprinter,
Z represents the stop signal of the teleprinter;

3. that the value of the frequency separation between adjacent frequencies employed should be the lowest of the preferred values compatible with the maximum telegraph speeds regularly used, the propagation conditions and the equipment stability;

4. that, when the two channels are not synchronized, it is desirable to limit the maximum rate of change of frequency to minimize the bandwidth of the emission.

RECOMMENDATION 347 **

CLASSIFICATION OF MULTI-CHANNEL RADIOTELEGRAPH SYSTEMS FOR LONG-RANGE CIRCUITS OPERATING AT FREQUENCIES BELOW ABOUT 30 MHz AND THE DESIGNATION OF THE CHANNELS IN THESE SYSTEMS

The C.C.I.R., (1956 – 1959 – 1963)

CONSIDERING

(a) that there exists a large number of long-range multi-channel radiotelegraph systems using frequencies below about 30 MHz and that it is desirable to classify them in categories;

(b) that the lack of uniformity in the arrangement and designation of the channels in these systems, may give rise to certain difficulties when one transmitting station has to work with several receiving stations;

(c) that the increasing use of multi-channel telegraph systems makes it desirable to adopt a uniform designation of channels in such systems;

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* Where modification of equipment is required, it is recognized that it may take some time before the coding systems indicated in this paragraph can be implemented on circuits between different Administrations.

** This Recommendation replaces Recommendation 248.

UNANIMOUSLY RECOMMENDS

1. that the systems should be classified and the different categories designated by letters, as follows:

1.1 *Time-division multiplex systems:* capital letter T (for example, synchronous systems, such as Baudot, RCA and TOR multiplex and double-current cable code);

1.2 *Frequency-division multiplex systems*

1.2.1 Systems with *constant* frequency arrangements of significant conditions: capital letter U (for example: voice-frequency multiplex with frequency shift);

1.2.2 Systems with *variable* frequency arrangements of significant conditions: capital letter V (for example: four-frequency diplex);

1.3 *Multi-channel systems using a combination of these processes*

1.3.1 Frequency-division systems, with constant frequency arrangement, combined with a time-division multiplex;	combination of the above-mentioned letters (always beginning with the frequency-division letters U or V)
1.3.2 Four-frequency diplex system, combined with a time-division multiplex system.	

2. when a multi-channel telegraph signal is applied to a multi-channel telephone transmitter, the designation of the telephone channel should come first in the sequence and should be in accordance with Recommendation 348-1;

3. when a multi-channel telegraph signal is applied to an independent-sideband transmitter used solely for telegraphy, the designation of the sideband should come first in the sequence. The letter H should denote the upper sideband, and the letter L the lower sideband;

4. that in time-division systems, the telegraph channels should be designated by capital letters A, B, C, D, etc.; for sub-division, the sub-channels should be designated by A1, A2, A3, A4, B1, B2, B3, B4, etc.;

5. that in frequency-division systems, the telegraph channels should be designated by figures;

6. that in a combination of multi-channel processes, the telegraph channels should be designated by a letter and figure sequence.

For example:

when using a frequency-division system with constant frequency arrangement of significant conditions (letter U), and modulating the 3rd channel of this latter system with a time-division multiplex (letter T), channel B of this latter system would be indicated by U3TB;

where channel B of the time-division system is sub-divided and sub-channel 2 is in use, the designation would be U3TB2;

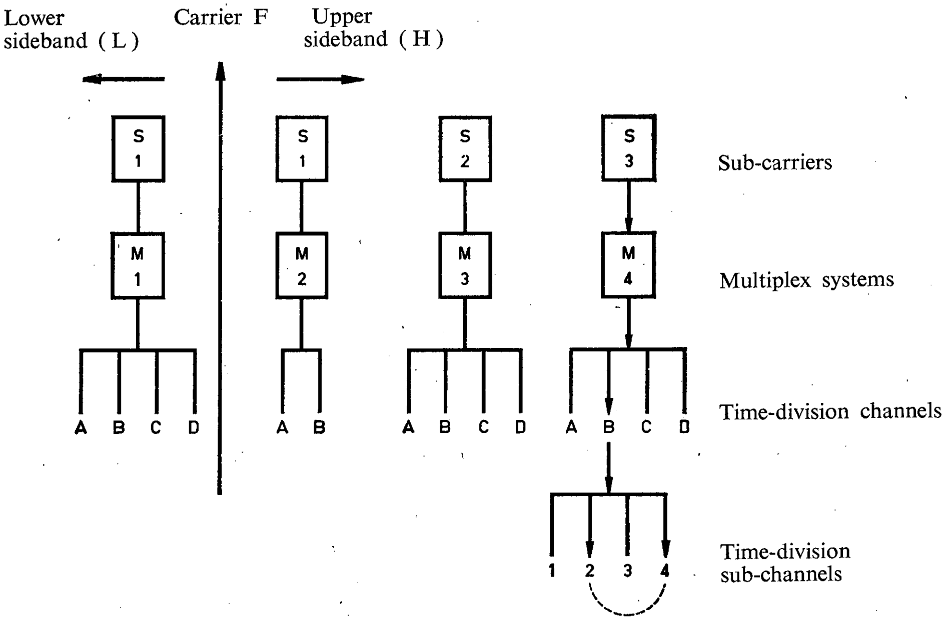
if the above-mentioned system is applied to channel B of an independent-sideband telephone transmitter, the corresponding designation would be BU3TB or BU3TB2;

if the above-mentioned system is applied to the upper sideband of an independent-sideband multi-channel transmitter used solely for telegraphy, the corresponding designation would be HU3TB or HU3TB2;

where additional information is required, the multiplex system may be identified by a number inserted between the letters T and B, and where two sub-channels (quarter-channels) are linked together to form a half-speed sub-channel (half-channel), each quarter-speed sub-channel component may be designated by the use of numbers separated by an oblique stroke.

The full designation HU3T4B2/4 would be applicable to the arrangement shown diagrammatically by the arrows on the right of the figure below·

in established communication networks, where the sub-carrier, multiplex system, channels and sub-channels arrangements are mutually known to the station management at each end of the circuit, it shall be permissible to shorten the full designation HU3T4B2/4 above, beginning at the first letter or number which is of major significance for identification purposes. For example, in the given instance 4B2/4 will identify the specific area illustrated by the arrows to the right of the figure below.



Multi-channel independent-sideband radiotelegraph transmitter

Note. —Sub-carriers are numbered sequentially in both upper and lower sidebands, starting with the number 1, adjacent to the carrier (radiated or suppressed).

RECOMMENDATION 348-1

ARRANGEMENT OF CHANNELS IN MULTI-CHANNEL SINGLE-SIDEBAND AND INDEPENDENT-SIDEBAND TRANSMITTERS FOR LONG-RANGE CIRCUITS OPERATING AT FREQUENCIES BELOW ABOUT 30 MHz

(Question 2/III)

The C.C.I.R., (1953 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that the lack of uniformity, in the arrangement and designation of the channels in multi-channel transmitters for long-range circuits operating on frequencies below about 30 MHz, may give rise to certain difficulties when one transmitting station has to work with several receiving stations;

(b) that, since it is necessary to economize in the use of the radio-frequency spectrum, when considering international circuits consisting mainly of single long-distance radio links, operating on frequencies below 30 MHz, it is desirable:

- to use independent-sideband transmissions to the maximum extent possible;
- to transmit a band less than the 300 to 3400 Hz recommended by the C.C.I.T.T. for land-line circuits;
- to reduce the upper frequency to 3000 Hz, or less in special circumstances, but never below 2600 Hz;

(c) that there are already in operation international multi-channel radiotelephone circuits, in which the bandwidth allocated to each channel is 3000 Hz, but are actually transmitting a speech band of 250 to 3000 Hz;

(d) that, in general, the outer channels are liable to cause and receive more interference to and from stations operating on adjacent assigned frequencies, the outer channels being those located furthest from the assigned frequency;

(e) that there are numerous transmitters in service which, when operated on a twin-channel basis, give rise to excessive cross-talk unless one of the channels is placed away from the carrier;

(f) that there are advantages in adopting channel arrangements which are the same in all parts of the HF (decametric) range;

UNANIMOUSLY RECOMMENDS

1. that standard channel arrangements should be adopted for multi-channel radiotelephone systems;

2. that the effective speech channel allocation should be 3000 Hz;

3. that the transmitted band in each speech channel should be from 250 Hz with an upper frequency of 3000 Hz, or lower in special circumstances, but never below 2600 Hz;

4. that in four-channel systems the channel arrangement should be as shown in Fig. 1*a*;

5. that, when less than four channels are used, the channels nearest to the carrier should be selected according to the arrangements shown in Figs. 1*b*, *c*, *d*, *e*, or *f*;

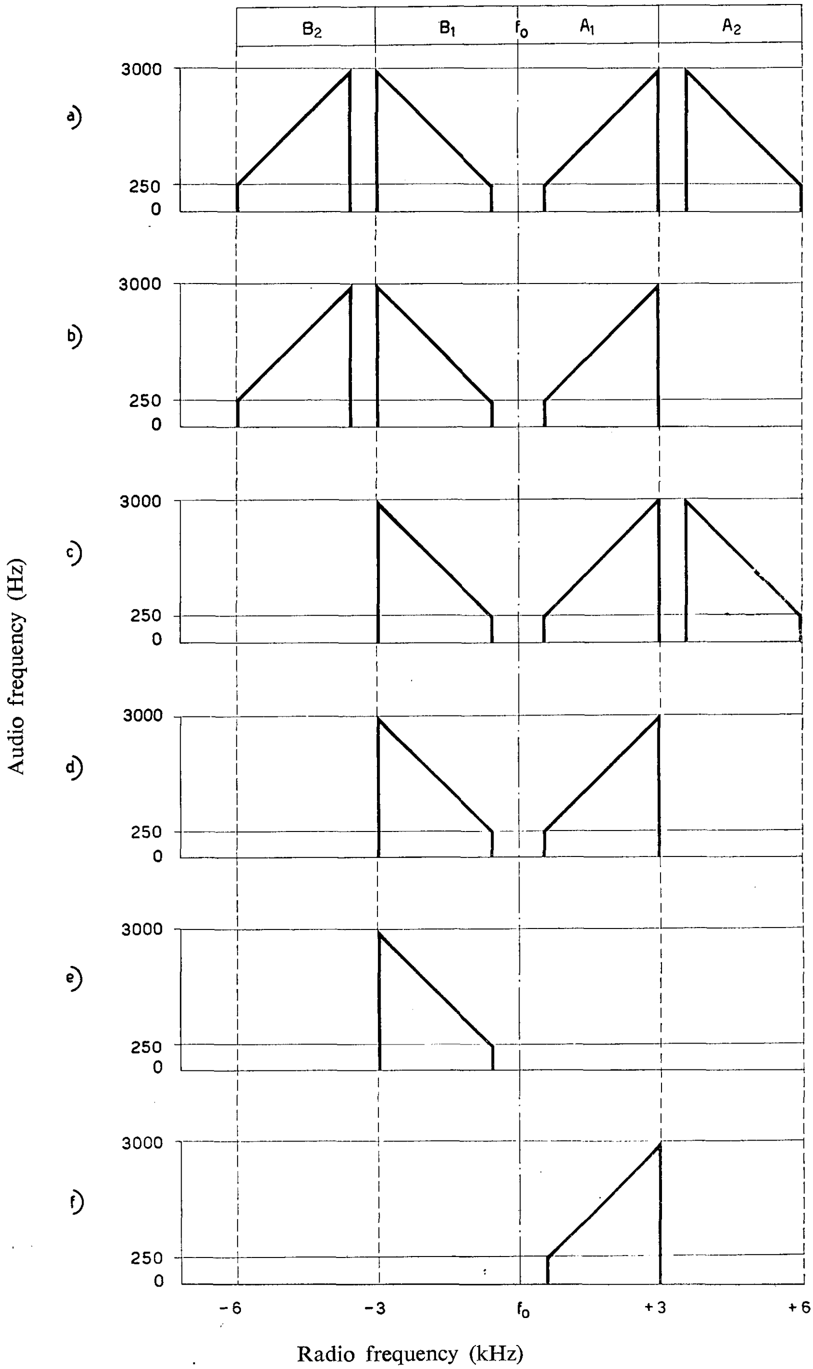


FIGURE 1

Relationship between audio-frequencies and radio-frequencies for the various channel arrangements

6. that with some transmitters in service, which do not give satisfactory operation with the arrangement shown in Fig. 1*d*, a channelling arrangement such as that shown in Fig. 2 may be used to minimize cross-talk;

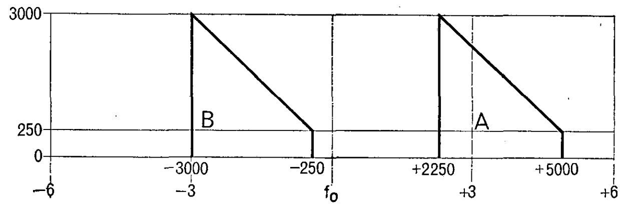


FIGURE 2

7. that the effective date of these arrangements be fixed by the next Administrative Radio Conference.

RECOMMENDATION 349-1

FREQUENCY STABILITY REQUIRED FOR SINGLE-SIDEBAND, INDEPENDENT-SIDEBAND AND TELEGRAPH SYSTEMS TO MAKE THE USE OF AUTOMATIC FREQUENCY CONTROL SUPERFLUOUS

(Question 182)

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that it is the practice with certain single-sideband (SSB) and independent-sideband (ISB) telephone systems, and with many telegraph systems, to employ automatic frequency control (a.f.c.) to adjust the receiver oscillator frequency in sympathy with variations in the frequency of the transmitted signal;

(b) that such automatic frequency control systems may give rise to difficulty under unfavourable conditions of propagation, at frequencies below 30 MHz;

(c) that the frequency stability, which can now be achieved, is much higher than that laid down in Appendix 3 to the Radio Regulations, Geneva, 1959, and is approaching a value which could provide sufficient inherent stability to enable automatic frequency control to be dispensed with;

(d) that, with systems dispensing with automatic frequency control, the frequency error of the modulating and demodulating stages and of the radio-frequency translating stages at the transmitting and the receiving ends, together with the frequency error due to the propagation path, contribute to an overall frequency error;

(e) that the overall frequency error of the complete system is decisive and that as far as feasible this error should be shared equally by both the transmitting and the receiving ends;

(f) that, however, in certain cases when narrow-shift telegraph systems are employed, reasons other than frequency stability of the equipment may still require the use of automatic frequency control;

UNANIMOUSLY RECOMMENDS

1. that the values of permissible frequency errors given in Table I, should be considered as suitable for use on systems giving access to the public service network and dispensing with automatic frequency control;

2. that the figures in column *(a)* of Table I are decisive for the system, and that those given in the columns *(b)*, *(c)* and *(d)* should be considered as an example as to how the overall frequency error could be split up into errors permissible in the parts constituting a complete system;

3. that, however, for multi-channel voice-frequency telegraph systems, the use of automatic frequency control may be retained (see Annex).

TABLE I

System	Maximum permissible overall error (Hz) (1)	Frequency error due to: Modulator stages (Hz) (2)	Frequency error due to: Demodulator stages (Hz) (3)	Frequency error due to the radio-frequency translating stages at both ends and to the propagation path (Hz)(3) (4)
1. Single-sideband and independent-sideband telephony	20	5	5	10
2. Radiotelegraphy:				
2.1 Two-tone multi-channel telegraphy with 340 Hz tone spacing and MCVF frequency-shift telegraphy with 30 Hz channel spacing	12(1)	3	3	6
2.2 Frequency-shift telegraphy (F1) (e.g. 50 baud, 200 Hz shift) and four-frequency diplex telegraphy (F6) using narrow-band filters at the receiving end	12	3	3	6
2.3 F1 and F6 systems using a limiter/discriminator at the receiving end, modulation index $\approx$ 2; (e.g. 196 baud 400 Hz shift)	20(4)	3	3	14
2.4 Phototelegraphy(2)	16	4	4	8

(1) See Doc.III/27, Geneva, 1962.
(2) For short-term frequency stability, see Recommendation 344-1. The figures under line 2.4 of this Table should be considered as provisional pending a reply by the C.C.I.T.T. to the questions put to it by the C.C.I.R. (see Doc.III/66 (Rev.), Geneva, 1962).
(3) This is the maximum error at the demodulator in the frequency of the carrier, if transmitted.
(4) For radiotelegraph systems, which use a device at the receiving end to correct for possible bias distortion due to frequency error, values larger than those indicated in the Table may be permitted.

ANNEX

FACTORS OTHER THAN FREQUENCY STABILITY WHICH MAY MAKE THE USE OF AUTOMATIC FREQUENCY CONTROL DESIRABLE

1. *Introduction*

The above Recommendation, which is a reply to Question 182 tabulates the permissible overall frequency errors for various systems. It excludes however, narrow-shift telegraphy.

2. *Relationship between distortion and frequency error*

A number of HF radiotelegraph circuits operating at modulation rates of about 100 bauds with a channel spacing of 170 Hz, use sub-carriers on independent-sideband transmissions.

Measurements made on various well-designed frequency-shift telegraphy receivers have indicated an increase in element distortion of approximately 1·25% for each 1 Hz frequency error. Poorer band-pass filter designs or narrower channelling will raise this distortion considerably.

It has been observed that frequency changes due to ionospheric propagation of up to 7 Hz may occur during periods of up to 15 min [1, 2]. This can, therefore, result in an additional distortion of up to 9%, which could be reduced by the application of automatic frequency control. Further information about the statistical distribution of these phenomena would be desirable to permit fuller evaluation of their effect on circuit efficiency.

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RECOMMENDATION 436

ARRANGEMENT OF VOICE-FREQUENCY TELEGRAPH CHANNELS WORKING AT A MODULATION RATE OF ABOUT 100 BAUDS OVER HF RADIO CIRCUITS

(Study Programme 17A/III)

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

CONSIDERING

(a) that lack of standardization in the arrangement of channels for voice-frequency multi-channel telegraph systems working over HF radio circuits can give rise to difficulties when setting up such systems;

(b) that it is necessary to use the radio-frequency spectrum to the best advantage in the interests of both spectrum economy and circuit efficiency;

(c) that frequency-shift systems are in use on many routes;

(d) that the frequency-exchange method of operation is in use on long routes suffering from severe multipath distortion;

(e) that on such systems, radiotelegraph channels which operate synchronously at a modulation rate of 96 bauds and employ automatic error correction are being increasingly used;

UNANIMOUSLY RECOMMENDS

1. that the channel arrangement shown in Table I be preferred for voice-frequency multichannel frequency-shift systems operating at a modulation rate of approximately 100 bauds over HF radio circuits;

2. that for frequency-exchange systems, the central frequencies of Table I should be used, and should be paired in the manner found to be best suited to the propagation conditions of the route. (A typical arrangement would take alternate pairs giving 340 Hz between tones.)

Note. – Theoretical work in Japan indicates an optimum frequency-shift of 0·8 B(Hz), where B is the modulation rate in bauds. This would lead to a required minimum bandwidth (at the $-$ 3 dB points) of B (Hz). Laboratory experiments and measurements on the synchronous ARQ circuit Frankfurt — Osaka, support these conclusions.

TABLE I

Central frequencies of voice-frequency frequency-shift telegraph channels with a channel separation of 170 Hz and a modulation index of about 0·8

(Frequency deviation: $\pm$ 42·5 Hz or $\pm$ 40 Hz)

Channel number	Central frequency (Hz)	Channel number	Central frequency (Hz)
1	425	8	1615
2	595	9	1785
3	765	10	1955
4	935	11	2125
5	1105	12	2295
6	1275	13	2465
7	1445	14	2635
		15	2805

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REPORTS OF SECTION C (FIXED SERVICES)

REPORT 19-1

VOICE-FREQUENCY TELEGRAPHY OVER HF RADIO CIRCUITS

(Study Programme 17A/III)

(1953 - 1966)

In principle, the voice-frequency telegraph systems describedin C.C.I.T.T. Recommendations R.35, R.35 bis, R.36, R.37, R.38A and R.38B are capable of being used over HF radio circuits, but the following considerations need to be borne in mind:

1. Specifications of performance in C.C.I.R. Recommendations do not normally follow the practice adopted by the C.C.I.T.T.

2. The ratio between the frequency spacing and the nominal modulation rate of the channels is greater in the C.C.I.T.T. Recommendations than that which is currently used for FDM-FSK systems in operation over HF radio circuits. The systems listed by the C.C.I.T.T. would consequently be slightly less resistent to noise, but slightly more resistent to the effects of multipath propagation than the narrower channels proposed by the C.C.I.R. Furthermore, the number of channels that can be used in a given bandwidth will be less.

3. Since the C.C.I.T.T. systems do not normally have to contend with fading, there may be insufficient protection by the receiving filters against inter-channel interference when the fading is frequency-selective. Also the range of levels over which the channel receiver should operate would need to be increased by at least 10 dB.

4. Systems for use over HF radio circuits should incorporate features which permit diversity reception.

Although it might appear convenient to have unified standards for line and radio systems, the divergent requirements referred to above will make this uneconomic. The characteristics of radio transmission lead to the operation of point-to-point channels with synchronous operation, and, ideally, regeneration at the radio receiving station. This is in contrast to the requirement, in landline systems, to be able to connect channels in tandem without regeneration and to transmit start-stop signals with acceptable quality.

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* This Report was adopted unanimously.

REPORT 42-1

USE OF RADIO CIRCUITS IN ASSOCIATION WITH 50-BAUD 5-UNIT START-STOP TELEGRAPH SYSTEMS

(Study Programme 17A/III)

(1953 – 1956 – 1963 – 1966)

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

– radio propagation is essentially variable,

– unwanted signals caused by noise or interference appear at the receiving end.

1. As a result of variations in propagation, a complex signal is supplied to the receiver, consisting of superimposed signals from several transmission paths with differential delays of up to several milliseconds (see Report 203). As a result, the telegraph signal appearing at the output of the demodulator suffers random distortion, the limiting value of which is practically independent of the signal-to-noise ratio.

Start-stop systems are particularly vulnerable to this form of distortion, because of the risk of a loss of synchronization produced by mutilation of a start or stop element (see Report 195, Fig. 4).

2. Various Administrations have, for several years, had in service, on certain HF circuits, equipment with a channel spacing of 120 Hz, the central frequencies and frequency deviations of which are given in Table I.

TABLE I

Central frequencies of voice-frequency frequency- shift telegraph channels with a channel separation of 120 Hz and a modulation index of about 1·4

(Frequency deviation: ±35 Hz or ±30 Hz)

Channel No.	Central frequency (Hz)	Channel No.	Central frequency (Hz)
1	420	11	1620
2	540	12	1740
3	660	13	1860
4	780	14	1980
5	900	15	2100
6	1020	16	2220
7	1140	17	2340
8	1260	18	2460
9	1380	19	2580
10	1500	20	2700

* This Report, which cancels Report 199, was adopted unanimously.

REPORT 106 *

IMPROVEMENT OBTAINABLE FROM THE USE OF DIRECTIONAL ANTENNAE

(Question 3/III)

(1953 – 1956 – 1959)

1. Introduction

Contributions by Administrations to the VIIIth Plenary Assembly, Warsaw, 1956, and to the interim meeting of Study Group III, Geneva, 1958, provide a basis for a preliminary report on the question of signal power gain, and signal-to-interference discrimination, afforded in practice by rhombic antennae. The experimental observations given by Docs. III/4 and III/31, Geneva, 1958, are summarized, as well as the pertinent Docs. 19, 139, 265, 320 and 532, Warsaw, 1956. The relation of these preliminary results to the median gain, given by Recommendation 162-1, is indicated.

In the text below:

l = length of leg (m),
φ = half the obtuse angle (deg),
h = height above ground (m).

2. Summary and discussion of reported results

Doc. III/4 (Federal Republic of Germany), Geneva, 1958, contains a summary (Table I below) of median values of measurements made, using a rhombic of a type in general service in the Post Administration, having $l = 115$ m, $h = 20$ m, $\varphi = 75°$. This first set of measurements was made relative to a *vertical antenna*; the results are otherwise expressed in Recommendation 162-1;

TABLE 1

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

In Doc. III/31, Geneva, 1958, there are also reported the results of observations of the gain of the rhombic antenna in the main lobe, relative to a half-wave horizontal antenna. These observations were, in the main, made at 15 MHz receiving WWV which transmits with an omni-directional antenna, but there is also one set of observations made at 18 MHz receiving PPZ which transmits with a directional antenna. The data show the realized gain

* This Report was adopted by correspondence without reservations.

to be less than the plain-wave gain in direction of maximum response, and to have a striking variability with time of day and/or signal strength. The data are not adequate to establish a systematic diurnal variation, but the 15 MHz data suggest that the greatest values of gain are realized at times of high signal intensity. This result is contradicted by the observations at 18 MHz of transmissions from a distant directional antenna, which emphasizes the need for additional observations and draws attention to the virtually certain dependence of all such observations on the *directivity of antennae at both ends of the path.* Table II below gives the decile and median values of the gain realized in these tests.

TABLE II

Period	Gain 10 % (dB)	Gain 15 % (dB)	Gain 90 % (dB)
Receiving WWV 15 MHz			
11 – 22 June 1956 130 observations	12·9	9·1	6·7
28 July – 6 August 1956 117 observations	15·2	11·7	7·7
29 Sep. – 11 Oct. 1956 217 observations	12·9	10·7	6·8
28 Feb. – 23 Mar. 1957 405 observations	10·8	7·1	0·0
15 – 25 January 1958 162 observations	11·1	8·5	3·2
Receiving PPZ 18 MHz			
29 Sep.–10 Oct. 1956	13·0	7·8	4·4

Doc. 139 (United Kingdom), Warsaw, 1956, gives results of the power gain and discrimination of rhombic receiving antennae, that is, off-azimuth response relative to maximum response. The measurements were made receiving distant transmissions 13 and 20 MHz, using a ring of 30 antennae having $l = 81$ m, $h = 23$ m, $\varphi = 70°$. The results are given in Table III for the main lobe and the forward arc (180°) excluding the main lobe, and for the backward arc.

TABLE III

Frequency	Main lobe gain (dB)	Gain relative to half-wave horizontal dipole(1) (dB)					
		Forward arc (180°) excluding main lobe			Backward arc (180°)		
		Gain 10 %	Gain 50 %	Gain 90 %	Gain 10 %	Gain 50 %	Gain 90 %
13·4 MHz (New York)	11	−2.5	−11	−19·5	−8·3	−12·7	−17
20·4 MHz (Pretoria)	15	3·5	− 5·0	−13·5	−4·3	− 8·7	−13
20·4 MHz (Pretoria)	15	2·5	− 6·0	−14·5	−9·2	−13·6	−18

(1) Median and decile values are relative to the arc, except for the main lobe.

More detailed data are given in the same document; an examination of the data for all observed azimuths has been made, and median values of gain obtained for the arcs specified in Recommendation 162-1, as follows:

TABLE III*a*

Frequency	Median value [1] of gain relative to half-wave dipole (dB)			Azimuthal range (degrees) (Rec. 162-1)		
	Main azimuth	Arc *A*	Arc *B*	Half of main arc	Arc $A_1 = A_2$	Half of arc *B*
13·4 MHz (New York)	11	−5	−13	12	21	147
20·4 (Pretoria)	15	2	−10	8½	18½	153

[1] Median values are relative to the arc, except for the main azimuth.

It is worth noting that values given in Table III*a*, with respect to discrimination against off-azimuth signals, are somewhat better than the values shown in Recommendation 162-1; it seems unlikely that values as favourable as those given in Tables III and III*a* are generally realized in practice. The value for arc *A* at 13 MHz is in fact better than might, at first sight, be expected; but, especially in arc *A*, the available data were not adequate to establish a median value with much confidence.

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

Antenna	*A*	*B*
Length l (m)	120	174·5
Height h (m)	33	29·5
Angle φ (deg)	71	70
Design frequency (MHz)	14·5	7·5

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

Doc. 320 (Japan), Warsaw, 1956, concludes that discrimination of greater than 15 to 20 dB cannot be relied upon; a number of observations are cited for values of discrimination (response outside the main lobe, relative to response in the main lobe), for a rhombic antenna having values of $l = 120$ m and $\varphi = 70°$ (height unspecified). These are shown in Table V; there were not enough data available to permit statistical analysis in terms of the arcs of Recommendation 162-1.

TABLE IV

Antenna	Frequency (MHz)	Gain relative to half-wave horizontal antenna (dB)									
		Main lobe				Distance (km)	Azimuth relative to main lobe (degrees)	Off-azimuth			
		Hours of obs.	Gain 10 %	Gain 50 %	Gain 90 %			Hours of obs.	Gain 10 %	Gain 50 %	Gain 90 %
A	7·7	83	9·4	8·3	6·7	2000	317	17	8·5	5·6	2·4
	13·7	158	13·4	11·4	8·8	3200	236	49	−7·3	− 8·7	−10·3
	13·7					9300	143	56	−2·9	−10·7	−13·5
	13·7					2000	14	14	1·8	0·5	− 1·4
	13·7					5800	37	42	6·1	4·5	0·2
	17·6	46	14·2	13·3	12·1						
B	7·7	30	15·0	11·4	7·6						
	13·7	50	13·7	11.0	9·2						
	17·6	34	9·9	7.8	6·0						

TABLE V

Median values of discrimination in decibels

(Off-azimuth response relative to main lobe)

Difference in azimuth (degrees)	Frequency ranges (MHz)					
	10·3 to 12·2		13·3 to 14·5		14·5 to 15·6	
	Discrimination (dB)					
	Median	Median standard deviation	Median	Median standard deviation	Median	Median standard deviation
6					3·8	2·1
12½			12·5	2·0	8·9	2·5
18½					8·0	3·2
21					9·8	1·4
22			7·5	2·9		
25½	9·3	1·4				
27					13·5	1·7
39½					12·5	2·1
46½					14·5	1·4
52½					17·6	2·0
79½			19·8	2·8		
93			12·5	3·6		
109½			20·3	3·8		
117	15·5	2·1				
168½			11·8	3·4		

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

3. Conclusions

The present data do not offer an adequate basis for revision of Recommendation 162-1. The results show striking variability of gain and/or discrimination with time, especially time of day and, to some extent, season of the year. There are undoubtedly important effects near times of sunrise and sunset, at times of signal failure on operating frequencies near the MUF, and at times of ionospheric disturbance when great azimuth deviations can be observed. Statistical correlation of values of gain with values of transmission loss would be of interest and the data expected from Study Programme 3A/III may be expected to show whether, and under which circumstances, such a correlation exists. The data given above suggest the extent of azimuth deviation encountered during normal propagation conditions. It must be noted that, because of the influence of irregularities in the ionosphere, such as give rise to azimuth-deviations, the directivity gain realized at the receiving terminal depends in a fundamental way on the directivity of the transmitting antenna — and vice versa. It is, therefore, important in carrying out observations (such as those outlined in Study Programme 3A/III), to specify the directivity of antennae at both terminals.

REPORT 107-1 *

DIRECTIVITY OF ANTENNAE AT GREAT DISTANCES

(Question 3/III)

(1959 - 1966)

1. Introduction

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

- the " Statistical method", a comparison of numerous observations of the same signal on different fixed antennae at the same location but at different orientations [1,2];
- mechanical rotation of antenna structures with various approaches to data statistics [3, 4];
- the " back-scatter " method, a comparison of back-scatter signals in a method similar to that of the statistical method [5].

Most of the studies have been made at high frequencies, although at least one was performed in the standard MF broadcast band [6].

References [3] and [4] indicate that, at moderately long distances the main lobes are on the average preserved, even under conditions of severe ionospheric disturbance. A more serious matter, which merits further study, is the question of preservation of nulls and front-to-back ratios. Reference [6] indicates that these are not preserved at medium frequencies.

* This Report was adopted unanimously.

Measurements of these effects are very difficult because of noise and interference. Besides, electrical balance, at both polarizations in antennae, feeders, and equipment antenna circuits, is a very critical matter in the realization of nulls and minima with rhombic antennae in ionospheric propagation [7].

References [8] and [9] deal with non great-circle effects. These effects were noted in the 1930's [10].

The effect of the propagation medium on transmission loss at different antenna orientations is dealt with in [11].

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

- Question 3/III – Directivity of antennae at great distances,
- Study Programme 3A/III – Improvement obtainable from the use of directional antennae,
- Recommendation 162-1 – The use of directional antennae.

Note. – It is noteworthy that in the IRE Standards on transmitters, modulation systems and antennae, 1948, the definition of directivity is: " the value of the directive gain in the direction of the maximum value ", thus differing from the usage in these documents.

2. Directivity in the vertical plane *

The results of measurements of the vertical angles of wave-arrival on a number of long distance HF routes received in the United Kingdom are reported (Doc. III/25, 1963 – 1966). Some of the experiments and the method of measurement used are more fully described elsewhere [12].

TABLE I

Statistical summary of measurements of vertical angles of wave-arrival in the United Kingdom

Transmitter	Distance (km)	Approximate frequency (MHz)	Months of measurements	Total number of measurements	Dominant vertical angle of wave-arrival not exceeded for the indicated percentages of all measurements		
					10 %	50 %	90 %
New York(1) (U.S.A.)	5500	13·4	May, June & July, 1961	4900	2°	9°	13·5°
Poona (1) (India)	7300	14·5	April, June & July, 1961	4434	3°	9°	13°
Sydney(1) (Australia)	17 000	14·7	June & July 1961	3780	4°	9°	13°
Barbados	6800	7·5	Aug. 1963 Nov. 1963 Jan. 1964	2954 798 437	2° 3° 3°	4° 6° 7°	7° 8° 10°

(1) These measurements were performed on antennae which were not particularly favourable to the reception of waves at low angles of arrival.

* Directivity in the vertical plane refers to the characteristics of an antenna measured from the ground in a vertical plane containing the transmitter and receiver.

The results are summarized in Table I and may be regarded as typical of circuits with propagation paths in latitudes of 50° or below.

Conclusions are drawn that signals over long-distance HF circuits are propagated via modes with angles of wave-arrival below 10° for a high percentage of time. The lowest path attenuation and the highest effective antenna gain will therefore be achieved with antennae having directivity characteristics in the vertical plane which favour these propagation modes at both transmitting and receiving stations.

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REPORT 109-1 *

RADIO SYSTEMS EMPLOYING IONOSPHERIC-SCATTER PROPAGATION

(Question 4/III)

(1959 – 1966)

A contribution, relating to Question 4/III, has been received from the U.S.A. (Doc. III/29, Geneva, 1958); references are cited in which information on ionospheric-scatter propagation relevant to exploitation of systems has been published [1,6]. Basic propagation characteristics are given in Report 260-1.

* This Report was adopted unanimously.

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

For estimation of the performance of fixed systems, it is important to know the variation with frequency, of the mean signal intensity, the fading characteristics, such as short-term amplitude distribution and fading rate, and the background galactic noise level. For practical purposes, received power may be considered inversely proportional to approximately the 7th power of the frequency, using scaled antennae. The background galactic noise is inversely proportional to the 7/3 power of the frequency. The resulting signal-to-noise ratio, using scaled antennae, is proportional approximately to f^{-5}. Studies have shown that the frequency dependence during hours of weakest signal intensity is not significantly different from that observed for the mean signal intensity. The short-term amplitude distribution of signal intensity approximates a Rayleigh distribution at frequencies observed in the range of 30 to 74 MHz. The typical measured fading rate (median crossings), at 50 MHz, is approximately 1 Hz: the fading rate is proportional to operating frequency raised to a power of 0·7 to 1·2, depending on conditions.

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

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

The propagation modes, most significant in long distance interference between scatter services and other services, are sporadic-E and F2. Adequate world-wide measurements of sporadic-E are not yet available to permit a complete evaluation of the percentage of time that interference is likely to occur. A comprehensive study of world-wide occurrence of Es observed at HF by ionosphere recorders has been published [7,8]. For practical purposes, ionospheric-scatter circuits, to avoid sporadic-E interference, should have their transmitting and receiving terminals geographically separated from other circuits or services by at least 2500 km. Figs. 1 to 3 of Report 260-1 represent contours of the F2-4000 km MUF exceeded for 1% of the hours for the December solstice, the June solstice and the Equinox, at sun-spot maximum. These are derived from standard C.R.P.L. F2-prediction data, using measured distributions of day-to-day values of F2 MUF about the median. A circle of 2000 km radius centred on the station gives the locus of frequencies at which propagation over 4000 km paths occurs 1% or 10% of the time during the season indicated. The percentage of the time is less for paths longer or shorter than 4000 km.

3. Radio-frequency and baseband characteristics of ionospheric scatter systems

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

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

- a single voice channel of response from 300 to 3100 Hz using SSB, or narrow-band frequency modulation with a peak deviation of 3 kHz;
- four to sixteen channel, time-division multiplex, at a rate of 150 to 600 bauds with frequency-shift keying; a separation of 6 kHz is commonly used between mark and space frequencies, to minimize errors due to Doppler components;
- combinations of the above, using linear transmitters, such as a voice channel and a frequency-shift keying system or two independent frequency-shift keying systems; as an alternative, two transmitters may be used, one carrying voice intelligence and the other teleprinter;
- a system has been proposed with a single voice channel and four teleprinter channels, using error correction and detection techniques at 177 bauds. A typical channel arrangement for 20 kHz spectrum occupancy is shown in Fig. 1;
- a frequency-shift radioteleprinter system using heterodyne frequency-changing, the oscillator frequency being chosen between the frequencies representing the two significant conditions of modulation (See Doc. III/112 (U.S.S.R.), 1963-1966) in such a manner that the upper beat frequency corresponding to one condition and the lower beat frequency corresponding to the other condition are both within a narrow band; among the advantages found for this method may be cited an increase in the signal-to-noise ratio and low cost.

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

- diversity reception is beneficial for voice or teleprinter operation. Dual or triple diversity is commonly used;
- the coherence bandwidth, as determined by multipath considerations of the transmission medium, is limited to approximately 3 kHz;
- meteoric multipath will, in general, limit the maximum modulation rate;
- during periods where the MUF may be above the operating frequency, F2, propagation may be expected. The above conditions are frequently accompanied by long-delay multipath echoes, ranging up to 50 ms or more. The echo pulses may have amplitudes comparable to or even greater than the desired signal, thus resulting in a very high error rate. Long-delay multipath problems may find solution by the use of antennae having more desirable directivity characteristics, the use of a frequency above the MUF, or by the use of special modulation techniques;
- ionospheric-scatter systems characteristically employ high power and highly directional antennae; during periods of sporadic-E or high MUF, they must be considered as potential sources of interference to other services sharing the same frequency band;
- current four-channel teleprinter systems, using dual-space diversity, typically require a signal-to-noise ratio of 24 dB (noise measured in a 250 Hz band), for a binary error rate of 1×10^{-4};
- voice systems currently in use will provide usable operator-to-operator quality over a single link with a radio-frequency signal-to-noise ratio of approximately 14 dB, as measured in a 3 kHz noise bandwidth.

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

The distance over which these circuits operate generally range from 1000 to 2000 km, and several of these circuits are now in operation.

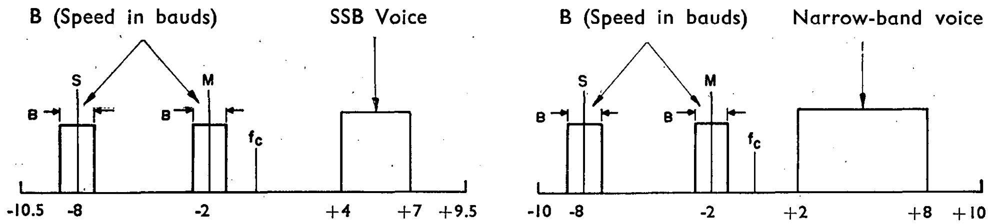

FIGURE 1

Typical 20 kHz channel arrangements for ionospheric-scatter transmission
(*B* is the frequency in hertz corresponding to the telegraph speed in bauds)

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REPORT 111 *

INFLUENCE ON LONG-DISTANCE HF COMMUNICATIONS USING FREQUENCY-SHIFT KEYING OF FREQUENCY DEVIATIONS ASSOCIATED WITH PASSAGE THROUGH THE IONOSPHERE

(Question 7/III)

(1959)

1. Introduction

This Report, based mainly on Doc. III/34 (U.S.A.), Geneva, 1958, deals with three aspects of the question. Firstly, the magnitude and time duration of the frequency changes to be expected are considered. Secondly, upper bounds of error rates for frequency-shift systems are calculated. Thirdly, experimental element-to-element phase changes are shown, relevant to phase-modulation techniques.

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

2. Characteristics of frequency changes over HF circuits

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

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

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

$$N_G = 1{\cdot}48\,\sigma$$

where σ is the standard deviation of an assumed Gaussian shaped band-pass filter. (This equivalent noise bandwidth refers to the received signal only and not the noise that may accompany it.) It is equivalent to the 2·17 dB half-bandwidth of the filter. If a rectangular filter is assumed then the fading rate N_R is

$$N_R = B/2{\cdot}32$$

where B is the bandwidth of the filter. The Gaussian shaped filter seems to be a close approximation to the true fading bandwidth of an HF signal [3]; however, for convenience, only a rectangular filter will be considered. Once we have a measure of the bandwidth of the fading

* This Report was adopted by correspondence without reservation.

signal, we may proceed to find the probability distribution of the instantaneous frequency along with several other statistics.

Fig. 1 shows the cumulative probability distribution of the instantaneous frequency. This curve has been normalized to the fading rate. For a fading rate of 1 Hz, the instantaneous frequency will be within about 20 Hz of the carrier frequency 99·96% of the time.

Taking into account the fading rate indicated in Report 266, the values of excursion of instantaneous frequency are not inconsistent with the deviations of 3 parts in 10^6 for a few milliseconds duration reported in Doc. III/3 (United Kingdom), Geneva, 1958.

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

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

3. The effects on frequency-shift keying of frequency changes due to passage through the ionosphere

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

If we assume a fading rate of one per second and a frequency shift of 40 Hz, we find, referring to Fig. 1, that the frequency of either the mark or space channel will change by 20 Hz and cross over into the wrong side of the discriminator for only 0·04% of the time. The 0·04% represents the upper limit of the binary error rate to be expected in the no noise case. If reference is made to Fig. 2, we find that $\overline{\Delta t}$ is only 6·2 ms; consequently, even when the instantaneous frequency does lie on the wrong side of the discriminator, its duration is so short that only rarely will an error be made.

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

4. Experimental data relevant to phase modulation

Several experimental studies have been conducted, to determine the performance of the frequency-shift keying systems and a phase-shift (synchronous) system over sky-wave transmission in the HF band. The phase-shift modulation system requires reasonable phase stability over an approximate period of 44 ms. Results of these studies are pertinent to this study of Doppler frequency changes.

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

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

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

5. Conclusions

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

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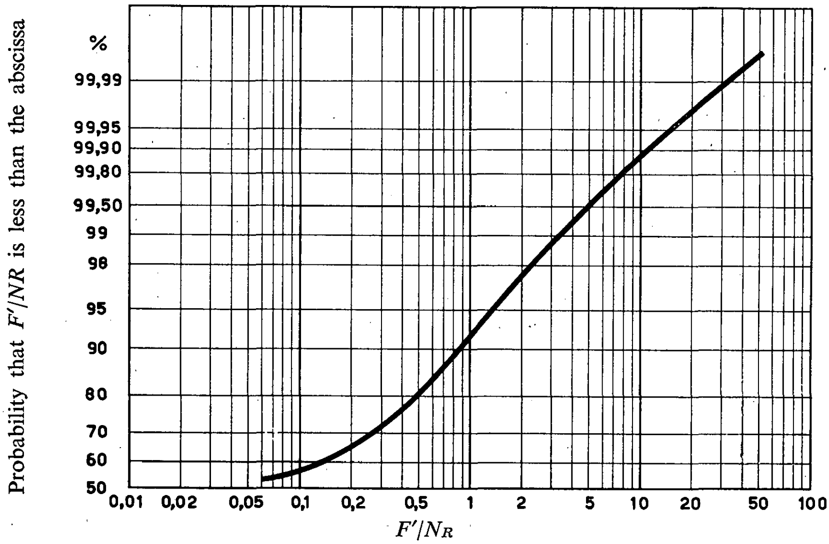
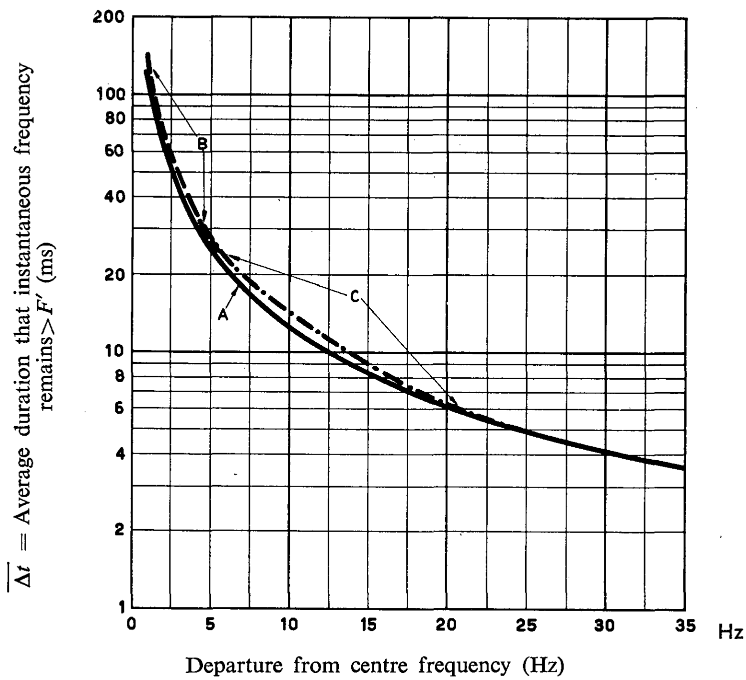


F' = Instantaneous departure from centre frequency (Hz)
N_R = Fading rate (fades per second)

FIGURE 1

Cumulative probability distribution of instantaneous frequency-change



Curve *A*: 0·2 fades/second Curve *B*: 1 fade/second Curve *C*: 5 fades/second

FIGURE 2

Average duration that instantaneous frequency change due to the ionosphere exceeds F′, with fading rates of 0·2, 1·0, and 5·0 fades per second (assuming a model of narrow-band Gaussian noise)

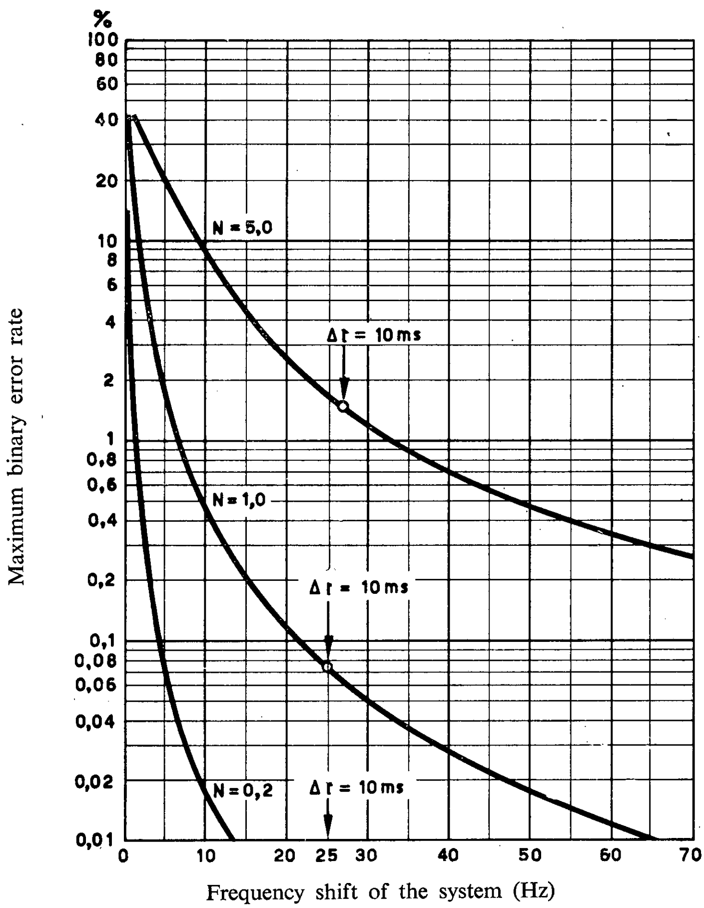


FIGURE 3

Relation between binary error-rate and frequency-shift of the system for fading rates, N, of 0·2, 1 and 5 fades per second.
Element length = 20 ms (50 bauds)

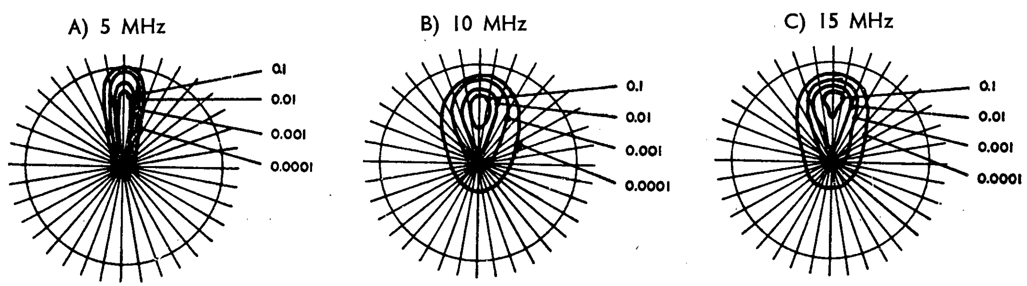


FIGURE 4

Polar probability contours of phase change and amplitude of WWV
The numbers shown represent the probability that a measurement will fall outside the contours.

REPORT 112 *

TRANSMISSION LOSS IN STUDIES OF RADIO SYSTEMS

(Question 1/III)

(1959)

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

Definitions and standard notations ** have been given in Recommendation 341 for the system loss L_s, the transmission loss L, the propagation loss L_p, the basic transmission loss L_b, the path antenna directivity gain G_p and the path antenna power gain G_{pp}. It is the purpose of this Report to illustrate the use of these terms and the concepts involved, and to show their relationship to other parameters.

2. Transmission loss in free space

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

$$p_a' = \left(\frac{\lambda^2}{4\pi}\right)\left(\frac{p_t'}{4\pi d^2}\right) \tag{1}$$

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

$$L_{bf} = 10 \log_{10} (4\pi d/\lambda)^2 \qquad (d \gg \lambda) \tag{2}$$

Since the free-space gain of a short lossless electric dipole is $g_t = g_r = 1{\cdot}5$, the path antenna gain for two optimally oriented short electric lossless dipoles in free space is:

$$G_p = G_t + G_r = 3{\cdot}52 \text{ dB} \tag{3}$$

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

$$L = 10 \log_{10} (4\pi d/\lambda)^2 - 3{\cdot}52 \text{ dB} \tag{4}$$

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

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

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* This Report was adopted by correspondence without reservation.

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

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

$$e^2/\eta_o = 1{\cdot}5\, p_r/(4\,\pi\, d^2) \tag{5}$$

where $\eta_o = 4\,\pi_c \times 10^{-7}$ is the impedance of free space (Ω), and $c = 2{\cdot}997925 \times 10^8$ (m/s), is the velocity of light in free space. The factor (1·5) can be identified as the free space gain of the transmitting dipole antenna. The radiation resistance of a short vertical electric dipole of effective length l at a height h_t, above a perfectly conducting plane, is given by:

$$r = \frac{2\,\pi\,\eta_o\, l^2}{3\,\lambda^2}(1 + \Delta t) = r_f\,(1 + \Delta t) \tag{6}$$

$$\Delta t = \frac{3}{(2k\,h_t)^2}\left[\frac{\sin\,(2k\,h_t)}{2k\,h_t} - \cos\,(2k\,h_t)\right] \tag{7*}$$

In the above, $k \doteq 2\pi/\lambda = 2\pi f/c$, i. e., λ is the wavelength in free space. Note that Δt approaches zero at large heights above the surface and r approaches its free-space value, r_f. On the other hand, $\Delta t = 1$ for $h_t = 0$, and the radiation resistance is then just twice its free-space value. The field intensity expressed in W/m² at a height h, for a short vertical lossless electric dipole at a height, h_t over a perfectly conducting plane surface, may be expressed by:

$$\frac{e^2}{\eta_o} \approx \frac{1\cdot 5\, p_r\,[2\cos^2\psi \cdot \cos\,(kh_t \sin\psi)]^2}{4\,\pi\, d^2\,(1 + \Delta t)} \tag{8*}$$

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

$$e = 2{\cdot}998962 \times 10^5\,(\sqrt{p_r}/d) \tag{9}$$

where e is in μV/m; p_r is in kW; and d is in km

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

$$a_e = \frac{1{\cdot}5\,\lambda^2\,\cos^2\psi}{4\,\pi\,(1 + \Delta r)} \tag{10}$$

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

$$L \approx 10\,\log_{10}\left\{\frac{[4\,\pi\, d/(\lambda\cos\psi)]^2\,(1 + \Delta t)\,(1 + \Delta r)}{(1{\cdot}5)^2\,[2\cos^2\psi\cdot\cos\,(kh_t\sin\psi)]^2}\right\} \tag{11}$$

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

$$\text{or } L = L_{bf} + A + L_t + L_r - G_p - 6{\cdot}02 = L_p + L_t + L_r \text{ (dB)} \quad (12)$$

where

$L_t = 10 \log_{10} [1 + \Delta t], L_r = 10 \log_{10} [1 + \Delta r]$ $G_p \approx 20 \log_{10} [(3/2) \cos^2 \psi]$ and $A \approx - 20 \log_{10} [\cos (k\, h_t \sin \psi)]$. It is of interest to note that the transmission loss between the dipoles on the plane perfectly conducting surface, $h_t = h_r = 0$, is the same as if the dipoles were separated by the same distance in free space, although the field intensity is 3 dB greater for the same power radiated. On the other hand, when the dipoles are several wavelengths above the perfectly reflecting surface ($h_t = h_r \gg \lambda$), and are separated by a large distance ($\psi \approx 0$), the transmission loss is 6·02 dB less than for dipoles separated by the same distance in free space.

The above is not the only logically consistent method of describing the gains and losses in the presence of a perfectly conducting ground. Thus, Schelkunoff, in the reference cited, considered the perfectly reflecting surface to be an integral part of the transmitting and receiving antennae, and set $G_{ts} = 10 \log_{10} [3/(1 + \Delta t)]$ and $G_{rs} = 10 \log_{10} [3/(1 + \Delta r)]$. In other words, he referred his maximum gains to those expected for isotropic antennae with the earth removed; this leads to a path antenna gain, referred to that expected between isotropic antennae with the earth removed, given by $G_{ps} = G_p + 6{\cdot}02 - L_t - L_r - A$, and this transmission loss is simply $L = L_{bf} - G_{ps}$. However, this method of approach is not recommended since:

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

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

4. Simplification possible at higher frequencies

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

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

It is desirable to relate the above transmission loss terminology to the terminology used in other C.C.I.R. documentation. We may express the free-space cymomotive force

$C = 20 \log_{10}(e.d)$ in dB rel. 1 V (e. g., relative to 1 V/m at a distance of 1 m) as in Recommendation 168-1 In free space, we find by (5), when we note that $P_t' = P_t - L_{tc}$ and $L_t = L_{tc}$:

$$C = 10 \log_{10} (p_r c.g_t \times 10^{-7}) = P_t - L_t + G_t + 14{\cdot}77 \text{ (dB)} \tag{13}$$

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

$$E = 10 \log_{10} [4 \pi\eta_0 p_a(r'/r_f) \times 10^{12}/(\lambda^2 g_r)] = P_a + 20 \log_{10} f - G_r + L_r + 107{\cdot}22 \text{ dB} \tag{14}$$

where f is in MHz.

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

$$L_s = P_t - P_a = C - E_C - G_p + 20 \log_{10} f + 92{\cdot}45 + L_t + L_r \tag{15}$$

where f is in MHz.

In Recommendation, 370-1, the curves of tropospheric field strength E, expressed in decibels relative to 1 µV/m, were referred to a free-space cymomotive force $C = P_t - L_t + G_t + 14{\cdot}77 = 46{\cdot}92$ dB relative to 1 V (i. e., 222 V), since they correspond to 1 kW radiated ($P_t - L_t = 30$) from a half-wave dipole ($G_t = 2{\cdot}15$); thus, the propagation loss corresponding to the values of E in those documents is given by:

$$L_p = L_s - L_t - L_r = 139{\cdot}37 - G_p + 20 \log_{10} f - E \qquad (C = 46{\cdot}92) \tag{16}$$

where f is in MHz.

The inverse distance field I (expressed in dB relative to 1 V/m at 1 m), may be determined over a perfectly conducting ground plane from (8):

$$I = P_t' - L_t + G_t + 20{\cdot}79 \text{ (dB)} \tag{17}$$

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

$$L_s = P_t - P_a = I - E_I - G_p + 20 \log_{10} f + 86{\cdot}43 + L_t + L_r \tag{18}$$

where f is in MHz

In Recommendation 368, the curves of $E = f(d)$ were referred to a value of $I = 20 \log_{10} 300 = 49{\cdot}54$ dB relative to 1 V, i. e., by (17) the inverse distance field corresponding to 1 kW radiated ($P_r = 30$) from a short vertical electric dipole ($G_t = 1{\cdot}76$) over a perfectly conducting ground ($L_t = 3{\cdot}01$) and thus the propagation loss corresponding to the values of E in Recommendation 368 is given by:

$$L_p = L_s - L_t - L_r = 135{\cdot}97 - G_p + 20 \log_{10} f - E \qquad (I = 49{\cdot}54) \tag{19}$$

where f is in MHz.

It is seen from the above discussion that the propagation loss, L_p, may be calculated by (16), from the values of E given in Recommendation 370-1, or by (19) from the values of E in Recommendation 368. The fact that there are different relations between L_p and the values of E in these documents, illustrates the complexity of the conventions used in past studies of radio wave propagation. There may be some advantage to the C.C.I.R. in adopting the propagation loss, L_p, between short electric dipoles, as a standard method of presenting the results of radio propagation studies such as those in the above documents. This would make possible the use of a *single* convention throughout the spectrum and would result in a presentation which is directly useful to those engaged in studies of radio systems. Short electric dipoles are suggested as reference standards for the uniform presentation of propagation data throughout the spectrum, in preference to either isotropic antennae or half-wave dipoles, for the following reasons:

– short electric dipoles are physically realizable throughout the spectrum;

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

It is recognized, that it will often be more convenient, at the higher frequencies, to make propagation measurements using half-wave dipoles, but such measurements can readily be adjusted to the results expected with a short electric dipole, since the maximum gain of a half-wave dipole is just 0·39 dB larger than that of a short electric dipole.

If the propagation loss, L_p, between short electric dipoles were used as a standard by the C.C.I.R., then $G_p = 3{\cdot}52$ dB and the field E ($C = 46{\cdot}92$) of Recommendation 370-1 could, by (16), be determined from:

$$E(C = 46{\cdot}92) = 135{\cdot}85 + 20 \log_{10} f - L_p \tag{20}$$

and the field E ($I = 49{\cdot}54$) of Recommendation 368 could, by (19), be determined from:

$$E(I = 49{\cdot}54) = 132{\cdot}45 + 20 \log_{10} f - L_p \tag{21}$$

where f is in MHz in both cases.

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

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

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

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

$$R = P_{td} - P_{tu} - L_{sd} + L_{su} \tag{22}$$

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

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

where P'_{td} and P'_{tu} are the radiated powers from wanted and unwanted transmitters, while L_d and L_u are the transmission losses for the wanted and unwanted transmission paths.

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

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

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

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

Questions: 3/III, 4/III, and 4/V;

Study Programmes: 4A/I, 1A/III, 3A/III, 6A/V, 11A/VI, 13A/VI and 17A/VI

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* It is convenient to choose these VHF receiving locations at the intersections of a regular lattice with separations of, say, 2 km, since it is known that there is very little correlation between the transmission losses at VHF for receiving points separated by such distances, and this will permit a maximum of information to be derived with a relatively small sample.

REPORT 195 *

BANDWIDTH AND SIGNAL-TO-NOISE RATIOS IN COMPLETE SYSTEMS

Prediction of the performance of telegraph systems in terms of bandwidth and signal-to-noise ratio

(Study Programme 1A/III)

(1959 - 1963)

1. Study Programme 1A/III sets out some questions, the answer to which would form a basis for the evaluation of the performance of complete systems. The questions include terms like " excellent service ", the interpretation of which depends greatly on the type of traffic the system is intended to carry and the grade of service. This Report will not discuss such questions in detail, but rather attempt to give a basis for a more objective method of performance specification in the light of recent work on communication systems.

Theoretical studies of the mechanisms of detection of telegraph signals in the presence of noise, having a Gaussian distribution [1, 2], have made it possible to define the performance of a system, in terms of element error-rate, as a function of the signal-to-noise ratio just prior to the detector. The word " detector " is used here in a very general sense and the detector might be a limiter-discriminator. It is convenient to use a quantity called the " normalized signal-to-noise ratio ", R, which is defined as the quotient of the average of the specific energies of the mark and the space signals, and the noise power per unit bandwidth. For systems which use two equally probable signals of equal energy, this ratio is equal to the signal-to-noise power ratio per baud per unit bandwidth, or the ratio of the signal power to the noise power per unit bandwidth, divided by the number of bauds. Direct comparison between receivers, even when working at different speeds is, therefore, possible.

In these studies, it was also found possible to specify the performance of a telegraph receiver by a single parameter. This parameter has been called the " demodulation factor " and it is the amount (in dB), by which the signal-to-noise ratio (normalized), applied to the receiver under test, exceeds that applied to an idealized receiver of the same type for the same element error-rate. For the purpose of this work, we have to distinguish between coherent and non-coherent receivers. The coherent receiver has *a priori* knowledge of the phase of the elementary waveform. The mark- and space-elements are assumed to be equally probable.

1.1 *Coherent reception. No fading*

Assume that $x_1(t)$ and $x_2(t)$ are the two signal waveforms, that τ is the unit interval (duration of one element), and that N is the noise power per Hz. Then if:

$$y^2 = \frac{1}{4N}\int_0^\tau [x_1(t) - x_2(t)]^2 \, dt,$$

the element error-rate P_e is given by:

$$P_e = \frac{1}{\sqrt{\pi}}\int_y^\infty \exp\left(-z^2\right) dz = \tfrac{1}{2}\operatorname{erfc}(y) = \tfrac{1}{2} - \tfrac{1}{2}\operatorname{erf}(y).$$

* This Report, which replaces Report 105, was adopted unanimously.

In terms of the " normalized signal-to-noise ratio ", R, this error-rate can be expressed in the form:

$$P_e = \tfrac{1}{2}\,\mathrm{erfc}\,(\alpha R)^{1/2};$$

- for phase-reversal modulation $\alpha_1 = 1$;
- for frequency-shift keying with two orthogonal signals $\alpha_2 = {}^{1/2}$;
- for amplitude keying (on-off signals) too, $\alpha_3 = \tfrac{1}{2}$.

For large values of R, the complementary error function can be well approximated by an exponential curve:

$$P_e \approx \frac{1}{2\sqrt{\pi\alpha R}}\exp\left(-\alpha R\right)$$

1.2 *Non-coherent reception. No fading*

For non-coherent reception of a steady signal, the error-rate is of the form:

$$P_e = \tfrac{1}{2}\exp\left(-\alpha R\right)$$

Again:

- for differentially coherent reception [3] of phase-reversal modulation $\alpha_1 = 1$;
- for matched filter reception and envelope detection [4] of frequency shift keying $\alpha_2 = \tfrac{1}{2}$ (for narrow-band FSK with shifts of the order $(0{\cdot}8/\tau)$, the effect of correlation leads to better results);
- for amplitude keying, we get approximately [4] $\alpha_3 = \tfrac{1}{2}$.

1.3 *Coherent diversity reception. Flat fading*

It is assumed that the fading is of Rayleigh type, that the fadings in different branches are uncorrelated (but that they are the same for mark and space signals), that the mean signal-on energies of all branches are equal, and that the fading is so slow, relative to the speed of signalling, that the signal power may be regarded as constant during any one signal element. The outputs of the diversity branches are assumed to be weighted, according to the signal energy and combined (maximal ratio combination).

For Rayleigh fading and one receiver, we get the following error-rate:

$$P_{e1} = \frac{1}{2} - \frac{1}{2}\sqrt{\alpha\, R/(\alpha\, R + 1)}$$

For dual diversity:

$$P_{e2} = \frac{1}{2} - \frac{1}{2}\sqrt{\alpha\, R\,(\alpha\, R + \frac{3}{2})^2\Big/(\alpha\, R + 1)^3}$$

For triple diversity:

$$P_{e3} = \frac{1}{2} - \frac{1}{2}\sqrt{\alpha\, R\,(\alpha^2 R^2 + \frac{5}{2}\alpha\, R + \frac{5}{2}\cdot\frac{3}{2}\cdot\frac{1}{2!})^2\Big/(\alpha\, R + 1)^5}$$

For quadruple diversity:

$$P_{e4} = \frac{1}{2} - \frac{1}{2}\sqrt{\alpha R \left(\alpha^3 R^3 + \frac{7}{2}\alpha^2 R^2 + \frac{7}{2}\cdot\frac{5}{2}\cdot\frac{1}{2!}\alpha R + \frac{7}{2}\cdot\frac{5}{2}\cdot\frac{3}{2}\cdot\frac{1}{3!}\right) \Big/ (\alpha R + 1)^7}$$

For large values of R, these results are closely approximated by:

$P_{e1} = 1/4\alpha R; P_{e2} = 3P_{e1}{}^2 = 3/(4\alpha R)^2; P_{e3} = 10\,P_{1e}{}^3 = 10/(4\alpha R)^3; P_{e4} = 35\ P_{e1}{}^4 = 35/(4\alpha R)^4$

respectively.

In the definition of the normalized signal-to-noise ratio R, the average signal energy and signal power per branch should now be substituted for signal energy and signal power respectively.

The basic curves, for idealized coherent reception of frequency-shift signals in fading ($\alpha = \frac{1}{2}$), are given in Fig. 1 for single, double, triple and quadruple diversity systems.

1.4 *Non-coherent reception. Flat fading*

The equations for the error-rate for non-coherent reception, under the circumstances otherwise specified in § 1.3. (maximum ratio combining), are:

$P_{e1} = \frac{1}{2}\ (1 + \alpha R)$, Rayleigh fading, one receiver;

$P_{e2} = \frac{1}{2}\ (1 + \alpha R)^2$, dual diversity;

$P_{e3} = \frac{1}{2}\ (1 + \alpha R)^3$, triple diversity;

$P_{e4} = \frac{1}{2}\ (1 + \alpha R)^4$, quadruple diversity.

The basic curves for this case are given in Fig. 2, again for the reception of frequency shift signals in fading ($\alpha = \frac{1}{2}$).

1.5 *Coherent reception. Independent fading*

1.6 *Non-coherent reception. Independent fading*

If it may be assumed that the frequencies corresponding to the two significant conditions of modulation are sufficiently widely separated for the fading in the two branches to be independent, then independent reception in the two branches is possible.

If, furthermore, the same assumptions are made as in §§ 1.3 and 1.4, the resulting error rates may be derived directly from the above. Then, going from flat fading to independent fading is equivalent to doubling the order of diversity, while having the power in each diversity branch [6].

2. Demodulation factor

If the performance curve of an actual receiver for coherent reception is of the complementary error function type, then a constant factor indicates the extent by which a practical receiver falls short of the ideal, and it is the same for all types of diversity.

Also, if the performance curve of an actual receiver for non-coherent reception is of the exponential type, the demodulation factor will be a constant.

Equipment for measuring the demodulation factor of a receiver in the laboratory, under simulated fading conditions, has been described elsewhere [5]. Alternatively, a measure of the demodulation factor may be obtained by calculation from the performance of the receiver under non-fading conditions, as in the Annex.

In this Report we have only discussed maximum-ratio combining. In the literature [7], one can find a comparison of this type of diversity with equal-gain and selection diversity. The loss for equal-gain combining is apparently of the order of 1 dB.

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

Relationships between element and character error-rates are shown in Fig. 3 and 4.

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

In Fig. 4, the upper limits are shown as follows:

- Curve 1: for a five-unit synchronous code: $P_c \approx 5P_e$;
- Curve 2: for a seven-unit code: $P_c \approx 7P_e$;
- Curve 3: for a five-unit start-stop system with tape printing and allowing for errors due to loss of synchronism, in addition to the simple character-errors $P_c \approx 17P_e$;
- Curve 4: for a five-unit start-stop system with page printing. i.e., including an additional allowance for multiple errors due to carriage return and line-feed failures. Again, as for the previous curves, errors in " letter shift " or " figure shift " are only counted once $P_c = 34P_e$.

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

First, we take the general case for reception of a steady signal.

Let R_o = the pre-detection signal-to-noise ratio (dB);

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

S = the modulation rate in bauds (elements/s);

B = the pre-detection bandwidth (Hz) of the receiver in question;

D = the demodulation factor of the receiver for the modulation rate specified, in decibels;

then
$$R_o = R_n + 10 \log_{10} (S/B) + D \qquad (1)$$

Example

A coherent receiver, having a pre-detection bandwidth of 1000 Hz, is used for 50 bauds, 5-unit synchronous working, using triple diversity. The measured demodulation factor of the receiver, for this signalling speed and bandwidth, is 10 dB. A character error-rate of 1×10^{-4} is permissible; what must be the pre-detector signal-to-noise ratio ?

From Fig. 4, the corresponding element error-rate is 2×10^{-5}. From Fig. 1, an ideal receiver using triple diversity produces an element error-rate of 2×10^{-5} for $R_n = 16$ dB.

Using equation (1), we find:

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

and inserting the known values we have

$$R_o = 16 - 13 + 10 = 13 \text{ dB.}$$

This is the required signal-to-noise ratio per branch. The signal-to-noise ratio after combining will be 3 R_o or 18 dB.

3. Conclusion

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

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

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ANNEX

In the absence of a fading simulator, it is possible to derive an approximate value of the element error-rate under fading conditions from the results of tests under steady conditions. These steady-state tests will give the error-rate as a distribution function g (R), of the normalized signal-to-noise ratio R.

If, for coherent reception, $g(R)$ can be expressed in the following form:

$$g(R) = \tfrac{1}{2} \operatorname{erfc} (bR/2)^{\frac{1}{2}}$$

then the demodulation factor is constant, 10 $\log_{10} b$, independent of the order of diversity employed.

In practice, this will not generally be the case and then the demodulation factor will be a function of both R, and q (the order of diversity). However, by an extension of the work in [2], it can be shown that, in general, the element error-rate with q diversity branches will be:

$$P_{eq} = [(q-1)!\, N^q]^{-1} \int_0^\infty y^{q-1} \exp\left(-y/R\right) g(y)\, dy.$$

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

$$(D_q)^q = [2^q \,.\, q!/(2q-1)!] \int_0^\infty y^{q-1} g(y)\, dy.$$

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

$$g(R) = \sum a_k . \exp\left(-b_k R\right)$$

Then for large values of R:

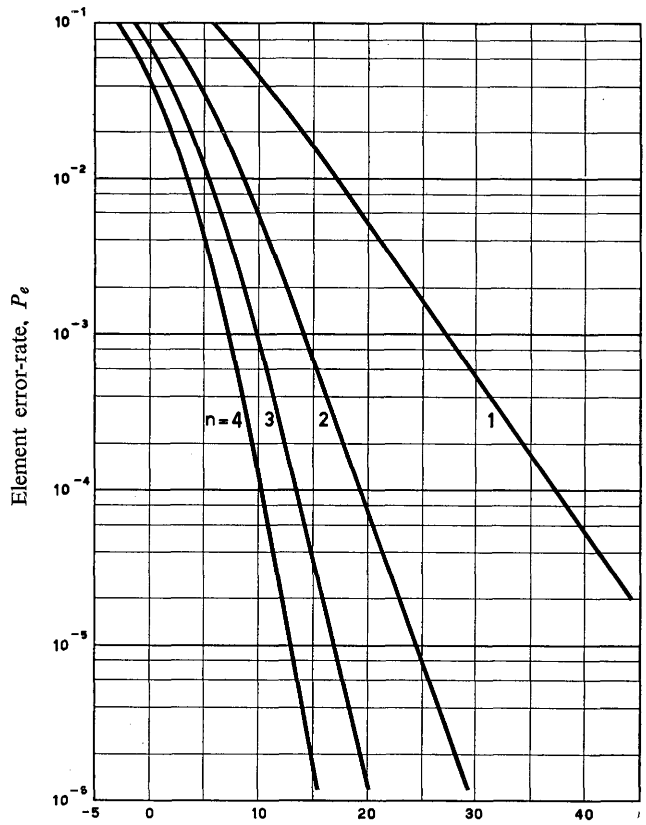
$$(D_q)^q = [2^q . q!(q-1)!/(2q-1)!] \sum (a_k/b_k{}^q)$$

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

For non-coherent reception, the reasoning is completely analogous. Again, the answer is simple, if the error-rate under steady conditions can be expressed as a single exponential form.

For the more complicated error performance given by a sum of exponentials, as above, the demodulation factor is given in this case by:

$$(D_q)^q = \sum (a_k/2)\ (2b_k)^q$$

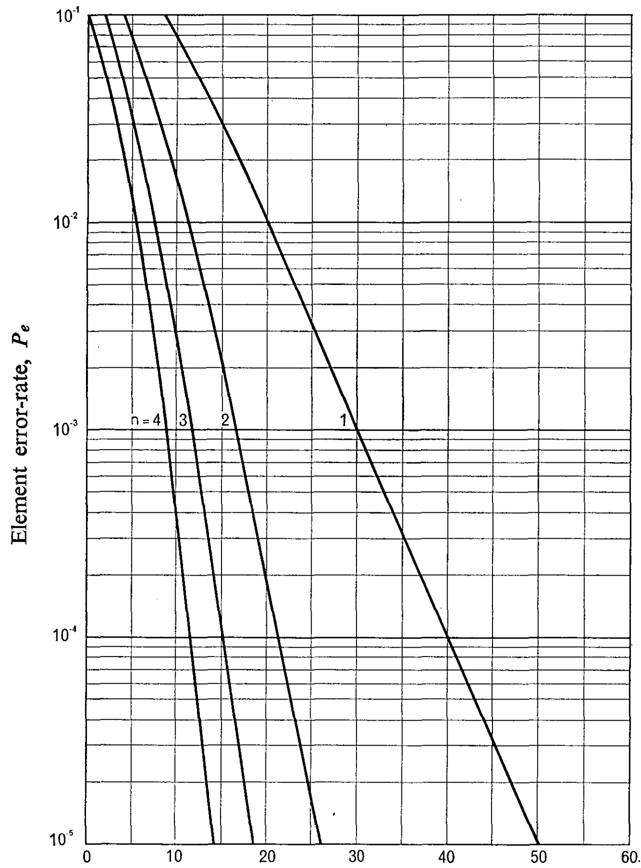


Normalized signal-to-noise ratio per diversity branch (dB)

$R_n = 10 \log R$ (n = number of diversity branches)

FIGURE 1

Coherent-reception



Normalized signal-to-noise ratio per diversity branch (dB)

$R_n = 10 \log R$ (n = number of diversity branches)

FIGURE 2

Non-coherent reception

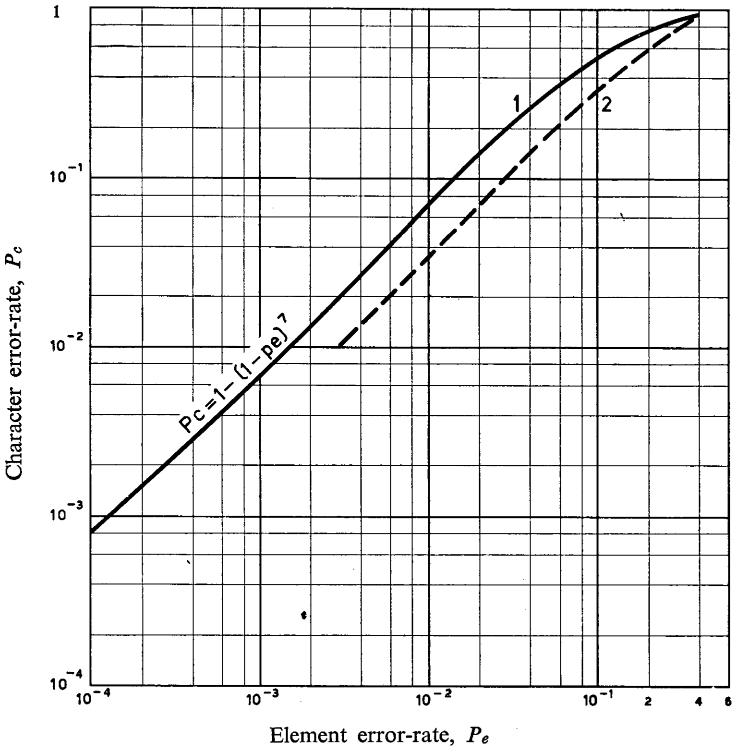


FIGURE 3

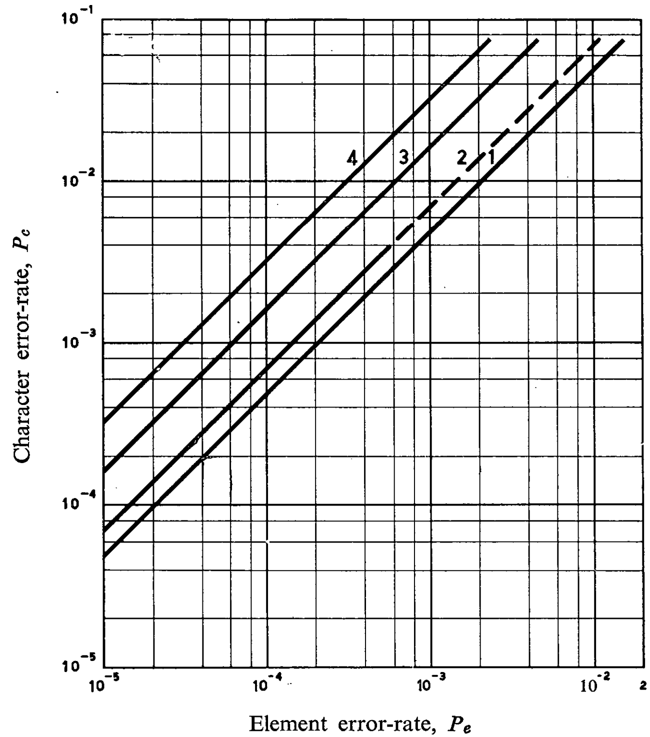


FIGURE 4

Curve 1: 5-unit synchronous code,
2: 7-unit synchronous code,
3: 5-unit start-stop, tape printing,
4: 5-unit start-stop, page printing.

REPORT 196-1 *

SOME ASPECTS OF THE APPLICATION OF COMMUNICATION THEORY

(Question 5/III)

(1959 – 1963 – 1966)

1. Introduction

Question 5/III has as its subject the relationships between permissible delay, residual uncertainty and bandwidth utilization. The residual uncertainty at the output can be calculated if the *a posteriori* probabilities that certain signals were transmitted are given at the received output. Instead, usually a decision is made, and the probability of error is calculated. We shall characteristize the channel by this error probability.

2. Block codes

The permissible delay is related to the length of the code. Assume first, that a block code [1] (each code word consisting of n elements) is used for error correction. The delay (from coding and decoding) is then at least $2n$ elements. If feedback is used and retransmission (as is done in ARQ systems [2]), for good signals, the delay will not change much. When the signal deteriorates the delay is likely to grow much larger.

If R is the rate at which digital information is transmitted (bits/second), and W is the bandwidth of a channel, S the signal power of the transmitted signal, and N the noise power (the noise is supposed to be white noise), then we have Shannon's relation:

$$R/W = \log\,(1 + S/N)$$

This relation gives the minimum signal-to-noise ratio required to provide a certain information rate per unit bandwidth, with a probability of error P_e, that can be made arbitrarily small by using a sufficiently large value of n (the length of the code). This is an asymptotical relation, and the question of how the probability of error goes down as n increases, has been studied by many writers. An early study was given by Rice [3]. For any noisy channel without memory having only a finite number of received signals, the error in transmitting information at a rate $H < C$ (C is the channel capacity) is bounded by an expression

$$P_e \leqslant F \exp\left(-B.n.\,(C-H)^2\right)$$

where F and B are constants depending upon the channel parameters but not upon H or n. This result was given in 1955 by Feinstein [4]. More accurate error bounds have since been derived by Shannon [5, 6], Fano [7], Zetterberg [8] and Gallager [9].

Using Shannon's results, Slepian [10] calculated the relation between the signal-to-noise ratio (S/N) and the information rate per unit bandwidth (R/W) for a number of given code length values n, and a given permissible error rate P_e (e.g. 1×10^{-4}). Upper and lower bounds for S/N are given. The upper bound gives the value of S/N for which codes with the required probability of error have been shown to exist, and the lower bound gives that value of S/N below which a code with the required probability of error cannot exist.

* This Report was adopted unanimously.

For $n = 25$ the distance between upper and lower bound is about 1 dB, and for $n = 101$ the distance is only 0·15 dB. (Slepian uses decimal digits). For a code length of 25 decimal digits, one needs 4 to 5 dB more than the asymptotical result of Shannon; and for a code length of 101 decimal digits about 2 dB, when the probability of error is 1×10^{-4}.

We do not yet know how to construct such good codes. However, block codes that can be decoded in a simple way, e.g. Bose-Chaudhuri codes have been used in practice. The decoding scheme guarantees correction of up to some fixed number of errors per block, and corrects nothing beyond. For algebraic block codes it is not yet known, how to use the *a posteriori* probabilities of error, this in contrast with the probabilistic decoding techniques of convolutional codes. For block codes it is not yet clear which combination of error detection or correction, use of null-zone thresholds, and automatic error correction, will give the best results.

3. Convolutional codes

Wozencraft [11, 12, 13] found that in his convolutional technique the complexity of the decoding operation goes up slower than the square of the length of the code, instead of growing exponentially with it. The decoding is simpler because the block structure is replaced by a tree structure, and the maximum likelihood decoder by a threshold decoder. The amount of computation required per digit is a random variable. This creates a waiting line problem at the decoder. ARQ is necessary when the buffer capacity is exceeded. Wozencraft showed also that the error bounds obtainable through the use of sequential decoding were essentially the same as those obtained for probabilistic block codes having the same constraint-length.

By combining signal design with sequential coding, an information rate of 7500 bits/s with an error propability of 1×10^{-9} was obtained as far as can be estimated from operation over a long distance telephone channel during 40 hours. The system is now [14] implemented for communication via active or passive satellite (e.g. the moon), with as its primary purpose, the communication of vocoded speech in a hostile environment.

Convolutional codes with orthogonal parity checks can be decoded very simply by Massey's threshold decoding [15]. It is most effective at relatively short constraint lengths. Low density parity check-codes have been studied by Gallager [16].

4. Burst-correcting codes

The effect of bursts on the 7/5 code automatic error correction system is discussed elsewhere (Report 197-1). The use of longer block codes for detection only may lead to a too high retransmission rate, see § 2. By interleaving n short block codes, which are capable of correcting one or two errors, bursts of length n or $2n$ can be corrected. This requires rather long guard spaces. (Burst error correcting codes are characterized by the maximum burst length, b, they can correct, provided the separation between bursts, the guard space, has a minimum length g.) Long cyclic codes are also suitable for burst error correction [17]. Their guard space to burst ratio is near the theoretical minimum.

A new development in convolutional codes is the adaptive convolutional code (Gallager). In this technique, mostly used in combination with sequential decoding, the guard space adapts to the actual length of the burst rather than remaining at the maximum value. In addition the guard space to burst ratio is significantly reduced by allowing a very small probability that a burst of less than the maximum length will not be corrected.

As already mentioned in §§ 2 and 3, even advanced codes will require automatic error correction when the channel is very poor.

A (15, 10) Abramson block code interleaved to give two-second burst error protection, tested at teletype speeds over an HF channel gave one order of magnitude improvement at a bit error rate of 1×10^{-2}, and two orders of magnitude at a bit error rate of 1×10^{-3}.

An adaptive coding system with maximum-burst error-correction of 6 s and a guard space a few bits longer than the actually occurring bursts, operated at telegraph speeds, led to 90% of error-free blocks, whereas diversity without coding only gave 15% error-free (50-line) blocks [18].

A short burst error correcting code for HF telegraphy transmission was found to allow for an 18 dB decrease in power for equal performance as a non-coded system.

5. Other advanced systems

Most communication channels are physically continuous even though they are used to transmit discrete codes. In the more obvious systems, discrete symbols are transmitted individually as time functions, and are reconstructed individually from continuous received signals. Lower error rates can be obtained by reconstructing code words as a whole, from received signals, rather than symbol by symbol. Application of matched filter techniques to detection of redundant code words is one illustration of this principle [19, 20].

6. Return channels (Question 5/III, § 2)

The channel capacity cannot be increased by the presence of a return channel, if the channels are totally independent. A return channel can be used very effectively to diminish the probability of error, even if the disturbances in the two channels are uncorrelated; however, the same result can, in principle, always be obtained by more complex coding procedures. New results on the use of feedback channels have appeared in the literature [21, 22]. Systems in which effective use is made of the correlation between noise in the go and return channel are, e.g., the Janet System, and a tropospheric-propagation system used in France [23].

7. Time-varying channels

Time-varying channels with delay spread have been studied by Price and Green [24], Siforov [25], Kailath [26] and Bello [27]. The Rake System, adapted to small values of the product of multipath duration and fading rate, has been described in detail.

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REPORT 197-1 *

FACTORS AFFECTING THE QUALITY OF PERFORMANCE OF COMPLETE SYSTEMS ON THE FIXED SERVICES

(Study Programme 1A/III)

(1963 – 1966)

1. Urgent need for information

The attention of Administrations is drawn to the urgent need for the information requested in Study Programme 1A/III, for several classes of emission. As requested in the Annex to Study Programme 1A/III, the establishment of minimum protection ratios for additional classes of emission under stable conditions should be given priority. It is realized that no Administration will be able to give all the answers, but partial answers are very welcome. This information will permit an improvement in the calculation of the probability of harmful interference between assignments and the consideration of the possibility of sharing.

* This Report was adopted unanimously.

The Study Group also needs the information to complete Recommendations 240, 339-1 and 340 and to bring them up to date *.

The documents received allow only a very partial answer to some of the questions proposed.

2. Number of transposition errors in automatic error-correction (ARQ) systems

In a study of the efficiency factor of a TOR circuit under varying signal-to-noise conditions, a relation was derived between the probability, v, of a correct character being printed and the attendant probability, p, of a transposition being printed [1]. One gets different theoretical limits for flat fading, uncorrelated fading and selective fading.

It has now been shown experimentally, that, under normal traffic conditions the results are nearly those expected for flat fading, or between those expected for flat fading and uncorrelated fading. Under unfavourable conditions, the results are more characteristic of those expected for uncorrelated fading.

For telegraph channels on which the errors occur in bursts a two state Markov process gives a suitable model for calculations [2]. In one state the probability of error is 0·5, in the other state the channel is error free. Moreover a third decision can be taken into account, when it is not sufficiently sure, whether a mark or a space was received. This suggests that the use of such a third decision may materially reduce the appearance of undetected errors at the output of an ARQ channel.

Calculations were made for selective and non-selective fading, and compared with results from several experimental circuits. The results with the model for selective fading fit closely the experimental curve. The values of error probability for non-selective fading are a factor of 50 – 100 higher in the region of practical interest.

3. Tables for the computation of distorted amplitude-modulation envelopes

When a signal consisting of a single frequency carrier modulated in amplitude by a sinusoidal signal passes through a dispersive medium (or filter) the envelope will be distorted. This distortion can be seen to depend on three parameters. For 6270 such triplets, the envelope contour has been calculated in 24 points, and also the harmonics up to the eleventh [3].

4. Error rates on long distance HF communications

Experimental results on long distance radiocommunications (2500 – 6000 km) in the West-East direction in the U.S.S.R. have shown that the erorr-rate depends not only on the signal-to-noise ratio but also on the distance. Diversity reception with an integrating regenerator was used. The reasons for the distance dependence need further study (time and frequency spread). In [4, 5, 6], statistical results are given for different operating speeds (282 and 141 baud), and different permissible error-rates (1×10^{-4}, 5×10^{-3}, 1×10^{-3}).

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REPORT 198 *

VOICE-FREQUENCY (CARRIER) TELEGRAPHY ON RADIO CIRCUITS

(Study Programme 17A/III)

(1963)

Theoretical work in Japan (Doc. III/23, Geneva, 1962), indicates an optimum frequency-shift of 0·8 *B* (Hz), where *B* is the number of bauds. This would lead to a required minimum bandwidth (at − 3 dB points) of *B* Hz. Laboratory experiments and measurements on the synchronous ARQ circuit Frankfurt-Osaka, support these conclusions.

It is to be noted, that this shift is preferably to be used on circuits near MUF and that otherwise a larger shift may be beneficial. For asynchronous circuits, some theoretical results indicate *B* to 2 *B* as best shift [Akima, Voss]. Further experiments, on circuits of different lengths, in different directions and in different seasons, are desirable before a definite conclusion can be reached.

REPORT 200-1 *

TELEGRAPH DISTORTION, ERROR-RATE

(1963 – 1966)

1. Distribution of telegraph distortion

The study of the relationship between telegraph distortion and error-rate has received further consideration. The statistical distribution of distortion can be of value for assessing the quality of a radiotelegraph circuit (see Report 351).

2. Isochronous telegraph distortion

2.1 The measurement of isochronous telegraph distortion can be applied meaningfully at several points in a radiotelegraph system.

* This Report was adopted unanimously.

2.2 In making measurements of isochronous distortion of the separate components of the system the following C.C.I.T.T. Recommendations should be taken into consideration:

Recommendation R.4 – Methods for the separate measurements of the degrees of various types of telegraph distortion.

Recommendation R.5 – Observation conditions recommended for routine measurements of distortion on international circuits.

Recommendation R.74 – Choice of type of distortion measuring apparatus.

2.3 The measurement of the variation in restitution delay is important in determining the fortuitous distortion contributed by the transmission medium.

2.4 Bias distortion is one component of the distortion produced by equipment and its measurement is useful in determining equipment performance.

3. Statistical measurements of error-rate, on the Warsaw-New York circuit did not indicate any direct relationship between error rate and the level of the received signal.

REPORT 201-1 *

REMOTE CONTROL SIGNALS FOR FACSIMILE TRANSMISSIONS

(Question 232)

(1963 – 1966)

1. Introduction

With the rapidly increasing use of facsimile transmissions for various purposes, using continuous web (chart type) recorders, it has become desirable for the C.C.I.T.T. to set up standards for the remote control signals to be employed for the connection, starting, phasing, speed control, stopping, etc. of a facsimile transmission.

2. Remote control signals for the meteorological facsimile service

The World Meteorological Organization, in collaboration with the C.C.I.T.T. has established a set of standards, including control signals for use over the leased weather network (see C.C.I.T.T. Recommendation 343).

3. Remote control signals for the subscribers' facsimile service

The C.C.I.T.T. proposals for the remote control of subscribers' apparatus for the transmission of business documents are given in Vol. VII of the Blue Book, p. 255.

4. Conclusions

These documents make known to the C.C.I.R. proposals for the standardization of remote control signals. The C.C.I.R. will study them to determine whether these signals are acceptable and applicable on radio circuits.

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* This Report was adopted unanimously.

REPORT 202 *

IDENTIFICATION OF THE CARRIER-FREQUENCY RELATIVE TO THE ASSIGNED FREQUENCY OF AN EMISSION

(Study Programme 19A/III)

(1963)

1. Introduction

The following method of carrier-frequency identification formed the subject of Doc. III/60 (U.S.A.), Geneva, 1962, and appears to provide a simple and precise method of identifying the carrier frequency of those classes of emission in which the carrier frequency and the centre of the assigned frequency band do not coincide. Examples of the application of this method are given in the Annex to this Report.

2. Description of method

2.1 *Represent the assigned frequency of the emission by X.* Let the *carrier frequency of the emission* be f_c;

2.2 determine the value of the difference ($f_c - X$), let this value be n Hz;

2.3 divide the value of n by 100 to obtain the code number;

2.4 if the value of n is negative (i.e. the carrier frequency lies below the assigned frequency), follow the value $n/100$ by the indicator X;

2.5 if the value of n is positive (i.e. the carrier frequency lies above the assigned frequency), precede the value $n/100$ by the indicator X;

2.6 the results obtained $\left(\frac{n}{100} X \text{ or } X \frac{n}{100}\right)$ give the location of the carrier frequency relative to the assigned frequency.

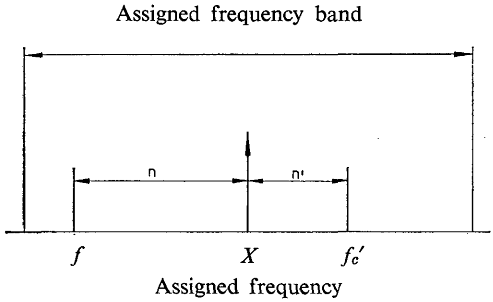
ANNEX

EXAMPLES OF THE APPLICATION OF THE METHOD

Existing station designation	Assigned frequency (kHz)	Carrier frequency (kHz)	Frequency difference (Hz)	Value $\frac{n}{100}$	Coded indicator	Coded station designation(1)
WEO86 A3 6840·5 kHz	6845	6840·5	−4500	−45	45*X*	WEO86 45*X*
WEO86 A 6844·1 kHz	6845	6844·1	− 900	− 9	9*X*	WEO86 9*X*
WEO86 B 6845·9 kHz	6845	6845·9	+ 900	+ 9	*X*9	WEO86 *X*9
WEP26 6851·8 kHz	6852·5	6851·8	− 700	− 7	7*X*	WEP26 7*X*
WER33 A 13448 kHz	13450	13448	−2000	−20	20*X*	WER33 20*X*
WES38 B 18942 kHz	18940	18942	+2000	+20	*X*20	WES38 *X*20
WMF27 B2 7717·7 kHz	7715	7717·7	+2700	+27	*X*27	WMF27 *X*27
WMH30 A2 10387·3 kHz	10390	10387·3	−2700	−27	27*X*	WMH30 27*X*

(1) For use in the exchange of operating information between the terminals of a radio circuit.

* This Report was adopted unanimously.



f_c is a carrier frequency designated $\frac{n}{100}X$

f_c' is a carrier frequency designated $X\frac{n'}{100}$

REPORT 203 *

MULTIPATH PROPAGATION ON HF RADIO CIRCUITS

Measurements of path-time delay differences and their incidence on typical radio links

(Study Programme 1A/III)

(1963)

1. Measurements on HF radio circuits of the fixed service

1.1 *Summary*

Some 4000 facsimile pictures, received over a number of important radiotelegraph circuits terminating in London, during the period from sunspot minimum to sunspot maximum (1953 to 1957), have been examined, to ascertain the incidence of multipath propagation and to measure the dispersion of path-time delays. Multipath conditions were found to obtain for a considerable proportion of the time throughout the whole period and path-time differences were observed up to 2·5 ms. The measurements were made on pictures received from New York (1420 pictures), Melbourne (1600 pictures) and Moscow (350 pictures), together with a few-less frequently used circuits. The technique of measurement is outlined below and is similar to that given by Japan in a contribution to the VIIth Plenary Assembly.

1.2 *Method of measurement*

The facsimile transmissions use frequency-modulation so that, in general, the received picture will be derived from the predominating path. If, due to fading, signals from different paths of unequal length predominate at different times, a sharp, straight line in the transmitted picture, at right angles to the line of scan, will appear as a jagged line in the received picture. By measuring the width of the ripple of the received line, it is thus possible to determine the

* This Report was adopted unanimously.

difference in propagation time over the shortest and longest paths that predominate from time to time during the transmission of the picture.

The spread in path-time delay, as seen on the facsimile pictures, was obtained by measuring the ripple on a line, at right angles to the direction of scan, which could be safely assumed to be sharp and straight when transmitted. A low-power microscope, having a graticule divided into squares, was used to measure the ripple. The magnification was adjusted so that one square represented a time difference of 2 ms for the machines most generally used. Displacements were estimated to the nearest 0·5 ms and, when a number of different delays were observed, only the maximum delay difference was recorded. In some cases, this maximum delay was not typical of the distortion throughout the picture as a whole.

A check was made under controlled conditions, using a fading machine which was adjusted to produce random fading with known differences in path-time delay and with various median signal levels on the two paths. The incidence of multipath observed in these tests was almost identical with that obtained by mathematical analysis.

1.3 *Measurement on facsimile pictures*

Each picture was examined to determine the maximum path-time delay difference. Since the values of delay were approximated to the nearest 0·5 ms, the probable distribution of differences in path-time delay between 0 and 2·5 ms was obtained by the usual method of apportioning the number of pictures at each value of delay, other than zero, equally between the adjacent delay ranges.

The incidence of multipath distortion on each picture was assessed according to four categories, viz: none, rate, frequent, continuous.

For each month, the percentages of pictures received for each range of delay difference and for each category of incidence were obtained. For simplicity, these monthly percentages have been averaged over a complete year, and the results are shown in Fig. 1.

1.4 *Discussion of results*

The results show that, for each of the four years 1953 to 1957, frequent or continuous multipath was in evidence on between 40 and 50% of the pictures analyzed. Approximately half the pictures affected by multipath showed path-time delay difference of 1 ms or more, and nearly 30% had delay differences of 1·5 ms or more.

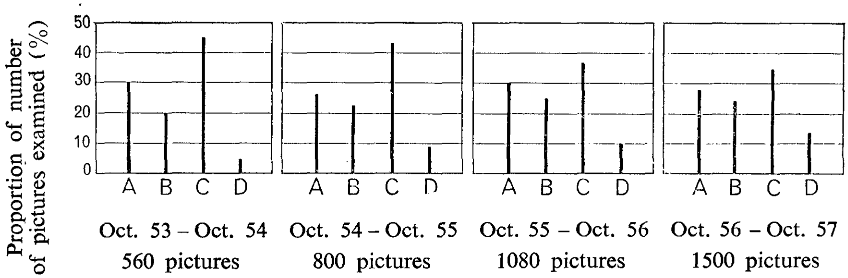
Multipath effects such as these are not particularly troublesome in facsimile transmission. Facsimile pictures have been used merely as a convenient means of obtaining data on incidence and delay difference over a long petiod on typical high-frequency fixed-service radio links. The effect of such multipath propagation could be more serious on telegraphy and data circuits, particularly where the path-time delay difference is appreciable in relation to the duration of the telegraph element. For example, a path-time delay difference of 2 ms would have an adverse effect on the performance of a telegraph circuit working at 200 bauds, since the delay difference is equal to 40% of the duration of the signalling element. Circuits working at lower modulation rates would be less affected by multipath propagation, since the path-time delay difference would be smaller in relation to the duration of the telegraph element. For example, a 2 ms delay difference would equal only 20% of the element duration at 100 bauds.

2. Measurement on meteorological broadcast services

Section 1 of this Report shows the incidence of multipath propagation and path-time delay differences observed on typical point-to-point high-frequency radio circuits. More severe multipath effects may, however, be experienced when frequencies below optimum have to be used. Such circumstances often arise, for example, in high-frequency meteorological broadcast services, and an analysis has been made of meteorological charts received in the United Kingdom by facsimile transmissions from Washintgon, D.C., and from Japan.

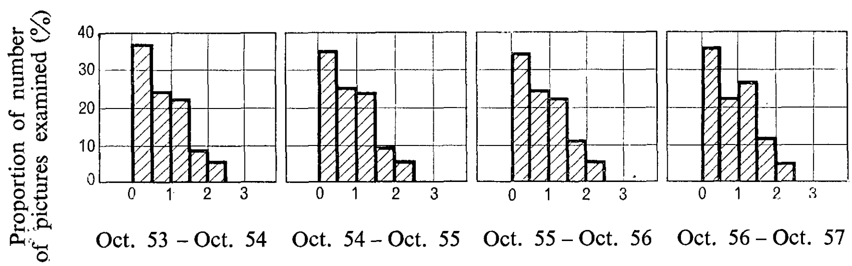
Some 1600 charts received during the period June to September, 1961, have been analyzed. Of these, 1000 were received from Washington and 600 from Japan. The method of measuring the path-time delay differences was similar to that described in § 1 of this Report. The results are tabulated below and are shown graphically in Fig. 2.

Multipath time-delay difference (ms)	Percentage of charts for each circuit	
	Washington, D.C. to United Kingdom (6000 km)	Japan to United Kingdom (9600 km)
0 – ½	10	0
½–1	20	5
1 –1½	28	9
1½–2	21	10
2 –2½	10	30
2½–3	6	26
3 –3½	2	11
3½–4	2	6
4 –4½	1	2



(a) *Incidence of multipath*

A – none
B – rare,
C – frequent,
D – continuous.



(b) *Range of multipath delay-differences (ms)*

FIGURE 1

Multipath propagation on HF radio circuits of the fixed service

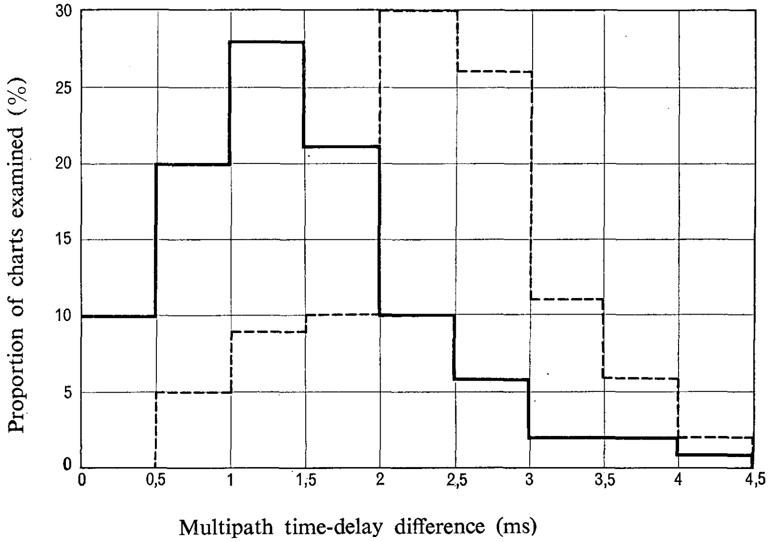


FIGURE 2

Multipath propagation on circuits of the meteorological broadcast service

——— Washington, D.C. to United Kingdom,

– – – – Japan to United Kingdom.

REPORT 345 *

PERFORMANCE OF TELEGRAPH SYSTEMS ON HF RADIO CIRCUITS

(Study Programme 17A/III)

(1966)

1. Introduction

This Report summarizes the results of an extensive series of tests in which different systems of voice-frequency radiotelegraphy are compared, both in the laboratory and on a real circuit. The systems treated in the laboratory are two-tone and narrow-band frequency shift modulation; results have already been published [1], but a summary of the major conclusions is given in § 2. Tests were also carried out on a differential phase-modulation system, but the results are excluded from this Report.

The results of a practical comparison, on a real circuit, of two-tone and narrow-band frequency shift is given in § 3.

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* This Report was adopted unanimously.

2. Laboratory measurements

2.1 *Description of systems*

It will be convenient to refer to the various systems by means of code designations defined as follows:

2.1.1 *System A* is a frequency-exchange or two-tone system using the method of detection described by Allnatt, Jones and Law [2]. Each channel can be regarded as comprising a pair of amplitude-modulation channels with complementary keying, separate detection and additive combination of the detected signals to produce a frequency-diversity improvement. For modulation at 100 bauds the modular spacing of the frequencies is 170 Hz. The two frequencies used for a channel may be separated by a multiple of this, being interleaved with the frequencies of other channels. The separation is chosen according to the most likely multipath propagation time difference, the optimum in herz being equal to half the inverse of this time difference in seconds.

2.1.2 *System B1* is a frequency-shift system with a channel spacing of 170 Hz [3]. The normal modulation rate of each channel is 100 bauds and the frequency-shift is 80 Hz. The channel receiver comprises the conventional limiter and discriminator arrangement. When diversity reception is used, the demodulated signals produced by each branch channel receiver are weighted according to the amplitude of the input signal to each branch.

2.1.3 *System B2* is a frequency-shift system of the same basic form but with a channel spacing of 340 Hz and frequency-shift of 170 Hz. The channels can accept a modulation rate of up to 200 bauds.

2.1.4 *Reference system*

To facilitate comparison between the systems, there is included with each set of performance curves one representing the hypothetical system mentioned in C.C.I.R. Report 195, which is based on the use of coherent detection of a non-fading signal.

2.2 *Method of testing*

The performance of each system has been measured in terms of mean element error rate versus normalized signal-to-noise ratio under various conditions of fading signal with added uniform-spectrum random noise. The transmission path was provided by a fading simulator [4] with facilities for simulating equal-activity two-path propagation (with selected path-time difference) and dual-space diversity reception.

2.3 *Test results*

Since the application of dual space-diversity reception is quite usual for telegraphy, the performance curves for that mode only are given here in Figs. 1 to 3.

In considering these curves, it should be borne in mind that, in system *A* (two-tone) the spacing of the significant frequencies was 510 Hz (i.e. three times the modular spacing); hence its optimum performance occurs when two-path propagation is present, with equal activity in both paths and a propagation time difference about 1 ms.

2.4 *Discussion of results*

The results will be discussed in the light of possible working requirements, first in terms of the normalised signal-to-noise ratio required for a given error-rate in the case of unprotected transmission, and then in terms of a given time-efficiency factor when an error-correction (ARQ) system is used.

2.4.1 *Unprotected transmission*

Different classes of user will tolerate various limits for accuracy, but it will be assumed in these comparisons that an acceptable mean error-rate is 1 in 10^4 elements corresponding to 1 in 2000 characters for synchronous 5-unit code transmission.

In the absence of multi-path propagation it would not, of course, be necessary to limit the modulation rate to one or two hundred bauds, but it will be of interest to compare the systems in this condition. However, on long-distance circuits, multi-path propagation with effective path-time differences in the range 1 to 2 ms is often encountered and must be taken into account. Under these test conditions systems *B* could not produce the required performance. System *A* would require a normalized signal-to-noise ratio ranging from 17 to 24 dB according to the actual path-time difference and relative activity of the paths.

2.4.2 *Protected transmission*

When automatic error-detecting and correcting systems are used on radio channels, the radio signal element error-rate may be permitted to rise considerably above 1 in 10^4 before the undetected error-rate approaches 1 in 2000 characters printed; no data is available on the exact relationship between detected and un-detected errors for each transmission system under fading conditions, but it is estimated that the increase could be by a factor approaching 10^2. Thus an element error-rate of 1 in 10^2 can be taken to define the upper limit of consideration. With similar conditions in each direction of transmission and assuming that errors occur randomly and without correlation between the two directions, this corresponds to a time-efficiency factor of 60–70%, i.e. about one-third of the circuit time is taken up by automaticr etransmission for correction of errors. An element error-rate of 1 in 10^3 will still produce an efficiency factor of approximately 97% with a negligible undetected character error-rate. Hence the range of practical interest in element error-rate of transmission systems can be confined between the limits 1 in 10^2 to 1 in 10^3. This leads to the conclusion that, a system having a residual error-liability which would make it undesirable for unprotected use can still be used with an ARQ system if it possesses other desirable features.

To illustrate the comparative performance of the systems in ARQ operation, curves of time-efficiency factor versus normalized signal-to-noise ratio, with space-diversity reception, have been derived from the element error-rate curves and are shown in Fig. 4. It has been assumed that the fading rate may be up to 20 per minute. With flat fading there are slight differences between systems *A* and *B*1 but for the sake of clarity only a single curve is shown; system *B*2 has been omitted since its performance at 100 bauds is not better overall than that of *B*1 and its performance at 200 bauds with a path-time difference of 2 ms would produce, an inferior efficiency. From these curves it is concluded that the order of merit would be *A*, *B*1 and *B*2 and, if fading conditions ranging between the extremes considered are assumed, that *B*1 needs approximately 3 dB better normalized signal-to-noise ratio than *A* to maintain 90% efficiency.

2.4.3 *Bandwidth utilization*

It is, however, unusual to encounter radio circuits engineered to such close limits that a difference in performance of 3 dB would be easily discernible in practice;

furthermore, frequency-band requirements of the systems have not so far been considered. For a given number of channels, System *A* will require almost exactly twice the bandwidth of System *B*.

Assuming that the best use is to be made of a conventional 3 kHz bandwidth, Table 1 shows the number of 100 baud channels which may reasonably be provided by each system and the aggregate signal-to-noise power required to produce various values of time-efficiency factor.

TABLE 1

Performance of a pratical fully-occupied nominal 3 kHz telephony channel

Type of system	Number of 100-baud channels	Aggregate signal-to-noise power ratio in a 3 kHz bandwith, to give stated efficiency (dB)		
		50 %	70 %	90 %
A	8	2 to 3	$3\frac{1}{2}$ to $5\frac{1}{2}$	$6\frac{1}{2}$ to 9
B1	16	6 to 7	$8\frac{1}{2}$ to 10	12 to 14

It is likely that the application of frequency diversity in addition to space diversity to System *B*1 would produce a performance comparable to System *A* as regards both channel capacity and signal-to-noise power ratio, at least over the range of error-rates of practical significance when used on protected circuits.

3. Comparison of systems A and B1 operating over a real circuit

A series of directly comparative tests was carried out over periods aggregating to four weeks on a 7200 km route between Singapore and Nairobi.

3.1 *Test arrangements*

The telegraph system between Singapore and Nairobi normally uses a six-channel two-tone equipment carrying a number of 96-baud ARQ aggregate signals of the Singapore to London circuit which are relayed at Nairobi. At Singapore the two lowest frequency channels of the two-tone system utilising frequencies of 765, 935, 1105 and 1275 Hz were suppressed and four frequency-modulation channels (shift 80 Hz) were injected into the composite signal on these frequencies.

One of the Singapore/London circuits, which is usually busy throughout the twenty-four hours, was selected for the tests and arranged to key both a two-tone (the component frequencies being spaced at 340 Hz) and a frequency-modulation channel so that the same information was radiated within a 3 KHz bandwidth on the two systems.

Adjacent channels on both the two-tone and FM-VFT systems were activated with different live traffic or reversal signals to simulate normal working conditions. Tone levels were adjusted so that equal peak powers were radiated by all tones as observed on a spectrum analyser.

At the Nairobi receiving station, the composite group of signals was received on a dual-path SSB receiver and fed to both the double-diversity two-tone and FM-VFT channel equipment.

Synchronous electronic regenerators were used to eliminate the distortion from channels on boths systems. Outputs from the regenerators which correct all distortion up to 48% were connected to electromechanical ARQ equipment modified to detect all incorrect 3: 4 ratios of the 7-unit ARQ signals. Counters were employed to register the mumber of errors detected, and hourly readings were recorded. The regenerators and ARQ equipment used for the two channels being tested were interchanged every twenty-four hours so that, should any hidden fault have developed in the equipment which could not be detected by normal means, it would have affected both channels equally. The output from the regenerator connected to the normal channel was also used to key the onward circuit to London.

In this manner, every effort to ensure a valid comparison of the two systems was made, and, in conjunction with reports from receiving stations logs, radio conditions reports, and distortion recorder charts, doubtful information which could have been caused by interference (QRM) was eliminated.

3.2 *Test results*

Each test run was taken over either seven or eight consecutive days and nights and the " errors detected " figures were examined. As the scatter of these hourly average figures would have given the graphs a saw-tooth shape, a running three-hour average figure was used for the error graphs.

The most useful criterion for the communicator is the percentage efficiency of the circuit, and as these error figures refer to only one direction of a normal ARQ circuit it is not possible to give an accurate assessment from the test results. However, by the use of a curve [5] reproduced here as Fig. 7, it is possible to estimate the effect the detected errors would have had on the percentage efficiency of the circuit if the return path had been error-free. Any detected errors on the return path, i.e. Nairobi to Singapore would have lowered the efficiency graphs, but the effect would apply equally to either system. (See Fig. 6). On this figure the efficiency expected from the receiving station logs is shown in shadow-graph form; the actual efficiency of the whole Singapore-Nairobi-London ARQ circuit for the period covered is also given.

3.3 *Discussion of results*

It will be seen from Fig. 5 that, in general, the two-tone system results were always better than the FM system results, even though the channels were of equal radiated power *. During the hours of " good propagation conditions " the errors per hour on either system were very few. However, as conditions deteriorated errors increased on both systems, but were more frequent on the FM system than on the two-tone system.

It is of interest to note that as the efficiency of the circuits decreases, the difference between the two systems generally increases.

4. Conclusions

These tests demonstrate that under difficult radio propagation conditions the two-tone system provides channels which have a higher efficiency factor than individual channels of an FM-VFT system when equal power per channel is used.

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* If the maximum number of channels were to be used in each case, a frequency-modulation channel would be 3 dB lower than a two-tone channel for the same aggregate peak envelope power.

However, if the major traffic load to be carried during the hours when radio propagation conditions are not unusually difficult then the larger number of channels given by the FM-VFT system, within a 3 KHz bandwidth is a great asset.

It should be noted that if the lower limit of Telex circuit-efficiency proposed by some members of Study Group X of the C.C.I.T.T. is recommended, i.e. Telex circuits are automatically " cleared " if the efficiency falls below 80%, then a situation could arise where for appreciable periods no Telex operation would be possible if an FM-VFT system were employed, whereas satisfactory operation would be obtained by the use of the two-tone system.

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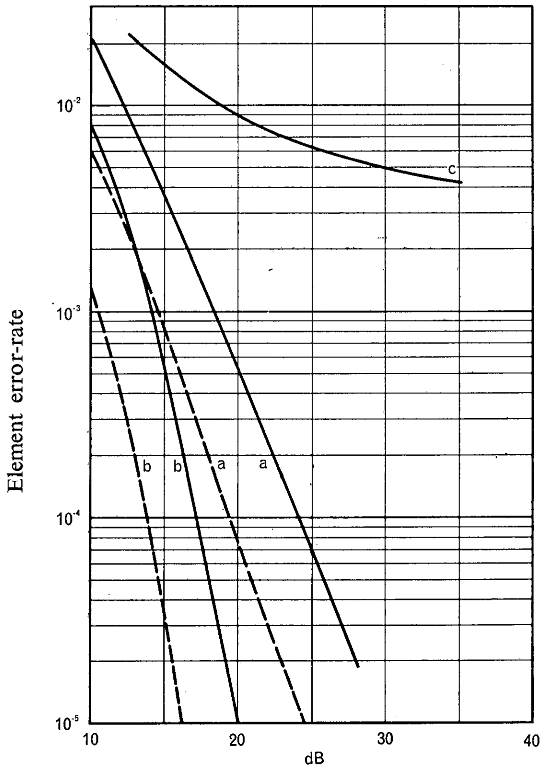


Normalized signal-to-noise ratio per antenna (dB)

——— System *A*

– – – – Reference system

a: flat fading and also a path-time difference of about 2 ms

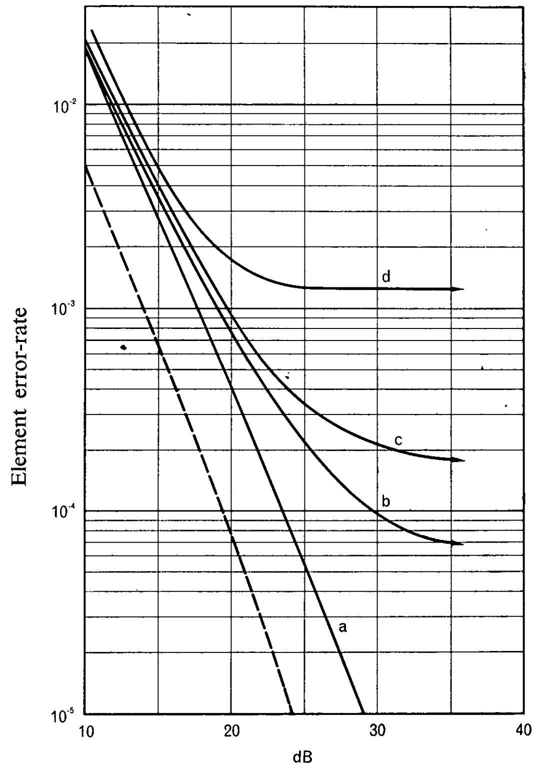
b: path-time difference 1 ms

c: path-time difference 4 ms

Modulation rate: 100 bauds; fading rate: 40 per min

FIGURE 1

System A. Dual space-diversity reception



Normalized signal-to-noise ratio per antenna (dB)

– – – – Reference system

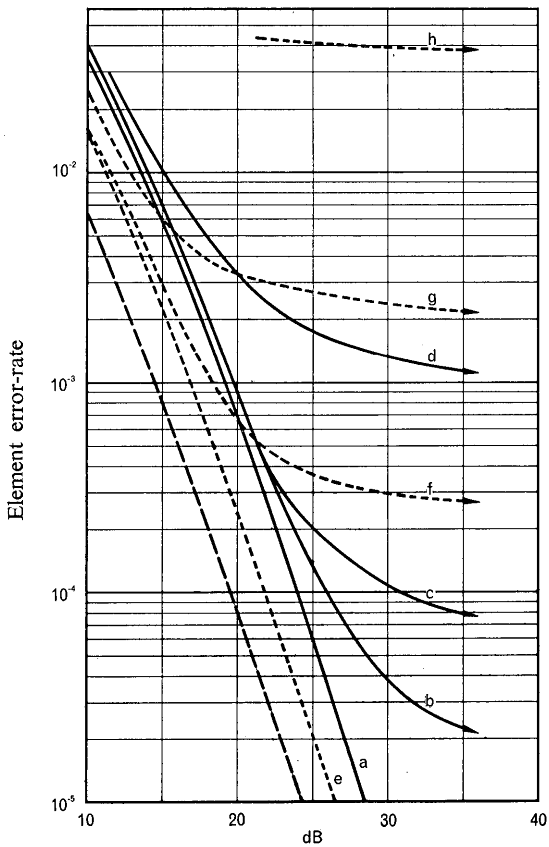
——— System *B1*

a: flat fading
b: path-time difference 0·5 ms
c: path-time difference 1 ms
d: path-time difference 2 ms

Modulation rate: 100 bauds; fading rate: 40/min

FIGURE 2

System B1. Dual space-diversity reception



Normalized signal-to-noise ratio per antenna (dB)

———— Reference system

———— System *B2*: modulation rate 100 bauds

System *B2*: modulation rate 200 bauds

a: flat fading

b: path-time difference 0·5 ms

c: path-time difference 1 ms

d: path-time difference 2 ms

e: flat fading

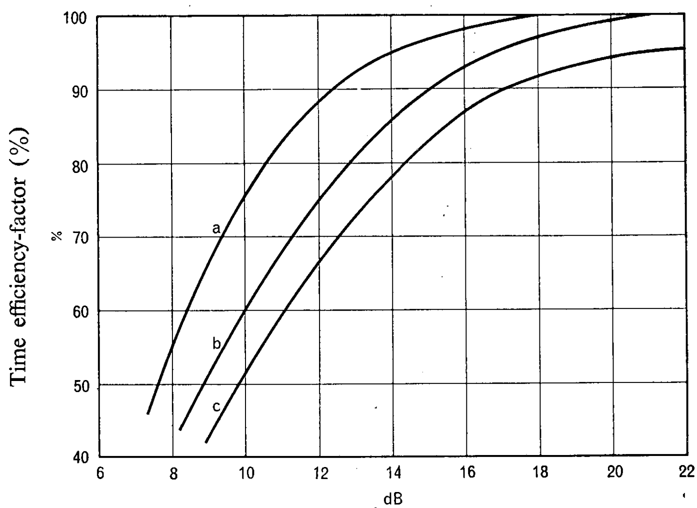
f: path-time difference 0·5 ms

g: path-time difference 1 ms

h: path-time difference 2 ms

FIGURE 3

System B2. Dual space-diversity reception



Normalized signal-to-noise ratio (dB)

a: System *A*. Path-time difference 1 ms (optimum for frequency-spacing)

b: System *A*. Flat fading and path-time difference 2 ms

System *B1*. Flat fading

c: System *B1*. Path-time difference 2 ms (in this case no frequency-diversity improvement is realized with a spacing of 510 Hz)

Modulation rate: 100 bauds

FIGURE 4

Time efficiency-factor

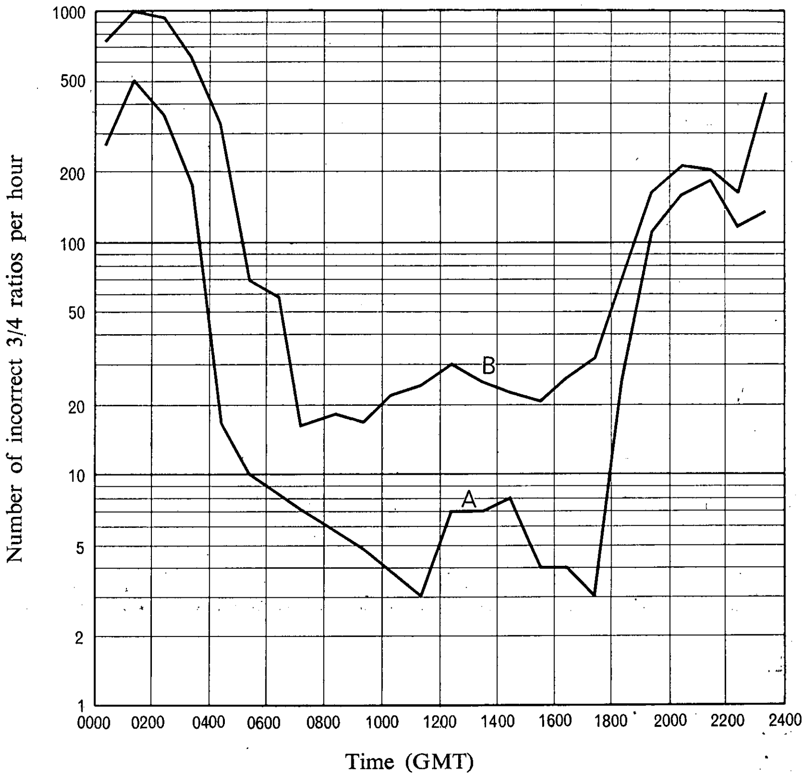


FIGURE 5

Typical performance curves

Average number of errors per day over three hours on the Singapore-Nairobi telegraph system during the period 26 March–1 April 1963

A: System *A* (two-tone) B: System *B1* (FM)

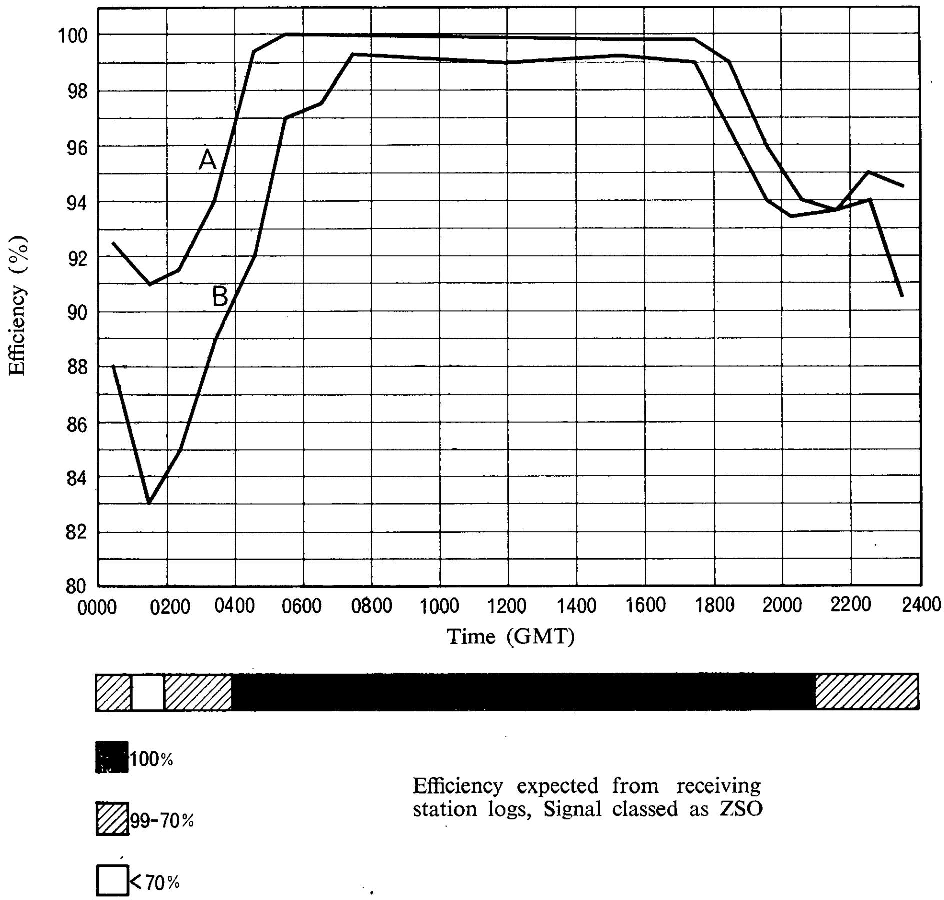
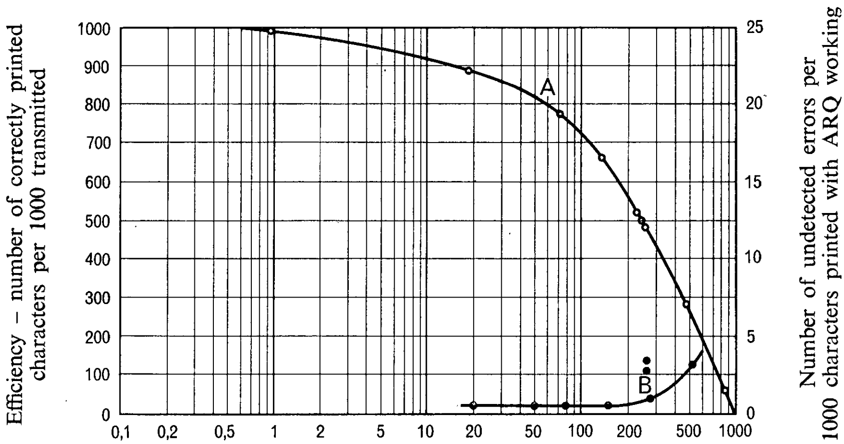


FIGURE 6

Estimated performance of error-corrected (in one direction only) systems (based on Fig. 5)

Measurements of average daily efficiency factor of the overall Singapore-London circuit for the period 26 March — 1 April, 1963 (Average daily efficiency of overall Singapore-London circuit for this period 90%)

A: System *A* (Two-tone) B: System *B1* (FM)



Number of mutilated characters per 1000 characters transmitted
(ARQ working, using gated ARQ and an error-free return path)

FIGURE 7

A: Efficiency of ARQ   B: ARQ undetected errors

REPORT 346 *

PERFORMANCE OF SYSTEMS USING PHASE-SHIFT KEYING OVER HF RADIO CIRCUITS

(Study Programme 17A/III)

(1966)

1. Introduction

This Report summarizes the results of a field test, in which the performance of two types of telegraph system using phase-shift keying, both employing four-phase modulation, are compared with a narrow-band system using frequency-shift modulation.* *

2. Description of systems

It will be convenient to refer to the various systems by means of code designations defined as follows:

2.1 *System B1* is a frequency-shift system with a channel spacing of 170 Hz [2]. The modulation rate of each channel was 75 bauds and the frequency-shift is 85 Hz.

2.2 *System C1* is a time-differential phase-shift keyed system (TD-PSK) according to the principles described in [3, 4], in which two information bits are phase multiplexed on each of twenty tones. All tones are keyed isochronously at a rate of 75 bauds, thus providing an aggregate data capacity of 3000 bits/s. Each receiving channel comprises two gated, very high-Q, mechanical resonators. These are connected alternately to the signal path during successive element periods, so that the incoming signal is integrated during one period and stored for reference use during the next. Phase comparison between the oscillations in the two resonators near the end of each element period effectively demodulates the signal. Each resonator is quenched at the end of its storage period, immediately prior to being reconnected to the signal input. The gating period of the signal (before integration) is somewhat less than the duration of the signal element length so as to reduce the effects of distortion occurring at the signal transition due to multipath propagation. Synchronization is obtained by means of a transmitted pilot tone.

2.3 *System C2* is a frequency-differential phase-shift keyed system (FD-PSK) according to the principles described in [5, 6], in which three information bits are phase coded on each of forty tone pairs (channels). All channels are keyed isochronously at a rate of 25 bauds, thus providing an aggregate data capacity of 3000 bits/s. In addition, twenty-two unmodulated reference tones are transmitted, spaced at regular intervals throughout the baseband, so that there are two information channels between adjacent reference tones. At the receiver, all tones are translated to a common processing frequency, the reference tones are extracted by means of narrow-band filters and phase-demodulation is effected by cross-

* This Report was adopted unanimously.

** Results of laboratory tests comparing one type of system using phase-shift keying with a two-tone system and a narrow-band system using frequency-shift modulation are given in [1].

correlating each signal tone with a phase reference obtained by linear addition of appropriate fractions of the two references which bracket the signal tone. A delay line in the information tones path provides compensation for the delay in the narrow-band reference extraction filters. By virtue of the long transmitted symbol compared to the prevailing multipath delay, spread-inter-symbol interference is minimized. Synchronization is obtained through the use of two unused channel positions and by comparison of the phase of the beat frequencies between successive reference tones with the receiver time base.

3. Comparison of systems B1, C1 and C2

The tests were conducted over an available commercial radio circuit from Pretoria, South Africa to Riverhead, Long Island, U.S.A., a great circle distance of approximately 12 700 km. The emission of the transmitters was a reduced-carrier, independent single-sideband (ISSB) signal, with a maximum of 12 kHz bandwidth consisting of four independent 3 kHz/s baseband slots. Both transmitter and receivers were frequency stabilized by means of synthesizers, providing frequency stability of 1 part in 10^8 per day. At the receiving terminal at Riverhead, the test signals were received in space diversity by two rhombic antennae, feeding the stabilized receiving system consisting of two receivers and two converters.

3.1 *Test arrangements*

Whenever possible, two systems were run simultaneously in the two 3 kHz slots on either side of the carrier (" dual mode "), with periodic sideband switching to average out any systematic channel inequalities. However, conditions of unequal QRM in the two slots often precluded this mode of operation. Under such conditions, the three systems were tested on a sequential basis, each system having an " on " period of fifteen minutes, with five-minute silent periods between successive test periods to evaluate channel noise and QRM.

To evaluate the performance of each system on an equal energy per bit basis, the available transmitter power was maintained constant while the voice frequency output level of each data system (drive) was set in accordance with the values computed to provide equal energy per bit. In these computations, the total composite signal powers of the PSK systems (including pilot tone and reference tone powers) was used as the basis for determining the energy per bit values.

Collateral data on the characteristics of the propagation medium were continuously monitored visually by means of two spectrum analysers and audibly by means of a loudspeaker. In addition, pen recordings were made of the a.g.c. voltages of the HF receivers. By comparing the a.g.c. level during the test run with the levels during the preceding and following five-minute off periods, a measure of received signal-plus-noise to noise ratio was available.

Manually set-up word generators were used to supply the modems at the transmitting terminal with a 52-bit binary sequence, and to detect errors at the receiving terminal. Sixteen bits of this pattern were used for sequence synchronization purposes. Bit timing for the word generators was derived from the timing clocks of the modem(s) under test.

The test circuit was operated during two 30-day test periods, which included the month of April, 1964, and the period from 15 June to 14 July 1964.

The accumulation of test data was hampered by all the usual difficulties of HF communications. In general, data runs could be attempted for only about 16 hours out of each 24-hour period. During the hours of 0100 to 0900 GMT the circuit was not usable because of extreme QRM or lack of signal strength.

The amount of QRM experienced throughout the entire test period was a particular difficulty. Some QRM was experienced at nearly all times of the day. At times, it was possible to sidestep this type of interference by moving the radio-frequency carrier by 500 to 1000 Hz in an attempt to move away from the interfering signal.

Finally, test data time was limited by circuit outages experienced during frequency change-overs. This problem was minimized whenever possible by frequency dualing when extra transmitters were available.

3.2 *Test results*

Fig. 1 presents the cumulative performance curves for the three systems, representing some 100 hours of recorded data and including periods of significant QRM and severe atmospheric noise.

Fig. 2 gives scatter-diagrams showing the comparative results of parallel runs between TD-PSK/FSK and FD-PSK/FSK. These results exclude data known to contain significant QRM or known to contain moderate to severe static (exceeding 100 static bursts per run). The diagonal in a scatter diagram is the locus of points of equal performance and divides the diagram in two fields. The result of each parallel run is plotted as a point in the diagram, with ordinates corresponding to the measured bit error-rate of each system.

3.3 *Discussion of results*

The FSK system was not operated at the optimum keying speed consistent with its channel characteristics [7]. (Theoretical considerations and experimental results show that, under conditions of constant energy per bit, this represents a penalty in the performance of the FSK system of approximately 0·5 dB; that is, at optimum modulation index, the FSK system would have required 0·5 dB less signal-to-noise ratio for a given error-rate. In addition, the aggregate data capacity of the FSK system used should be considered to be 1600 bits/s in a 3 kHz channel.)

The results presented in Figs. 1 and 2 show that both PSK systems performed about as effectively as the particular FSK system tested. The " goodness " criterion for the type of curves of Fig. 1 is quite evident as long as the curves do not cross over. A cross-over may result from the type of time distribution of error-rates, and the inclusion of sequential runs, where the amount of data, especially at the lower error-rates, may not be sufficient to ensure averaging out of differences in channel conditions.

The apparent randomness of the scatter diagrams of Fig. 2 is typical of HF communications. Similar results can be obtained when comparing individual channels of a single multi-channel system.

Observed values of multipath spread were in general between 1 and 2 ms, with occasional values of up to 3 or 4 ms. The tests were conducted during a year of low sunspot activity, and larger values may therefore be expected for this circuit under conditions of higher sunspot activity. The observed values, however, are not abnormally low for many circuits; although values in excess of 4 ms may be encountered during 1% to 2% of the time (Report 203).

4. Use of bit-synchronous systems on protected circuits

Present day practice tends to identify a channel of a multi-channel voice-frequency telegraph system with a given number of ARQ channels, for example, it is common practice to send two-channel ARQ (96 bauds) over each channel of a narrow-band (170 Hz spacing) FSK system. The fact that the channel rates of PSK systems are often not directly compatible with the ARQ rate, and the need for isochronous keying of all channels in unison, have been cited as a disadvantage of these systems. However, PSK systems, as in the examples, have capacities which are multiples of 300 bits/s, e.g. by using six-channel ARQ operation (288 baud) on channel blocks of 300 bits/s capacity, the loss in efficiency of the PSK systems would be not more than 4%. Furthermore, the synchronous character of the PSK systems, coupled with an intelligent use of the " spare " bits, may well prove to be of considerable value inautomatic phasing of the ARQ systems in multi-channel point-to-point operation. For the introduction of PSK systems on ARQ circuits, operational procedures have still to be developed.

5. Conclusions

The limited duration of the tests preclude definite conclusions with respect to the relative performance of PSK and FSK systems for ionospheric transmissions. However, the tests demonstrated that, under conditions reasonably typical for systems of the fixed service, the four-phase PSK systems compared to a conventional two-level FSK system were capable of providing increased bandwidth efficiency without penalty in error-rate, or total power, for the same amount of information transmitted.

6. General remarks

The tests discussed in this Report refer only to a limited number of systems. Other techniques may be able to achieve equal or better results.

Members of the C.C.I.R. are urged to submit results of tests of any such systems.

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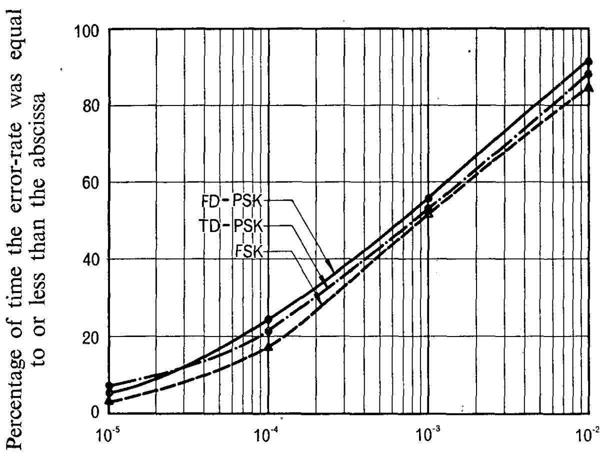

Figure 1

Cumulative performance curves

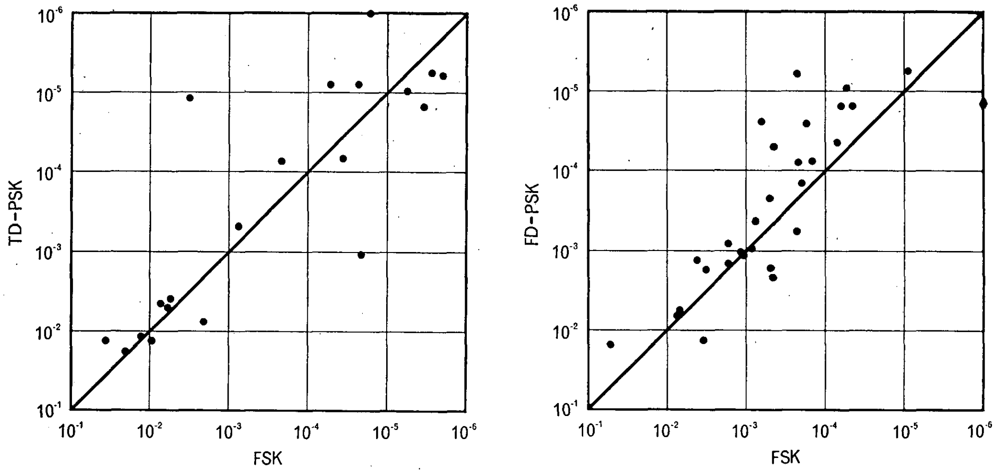

FIGURE 2

Scatter diagrams of error-rates for parallel runs

REPORT 347 *

VOICE-FREQUENCY TELEGRAPHY OVER RADIO CIRCUITS

(Study Programme 17A/III)

(1966)

On certain radio circuits with special characteristics (e.g. North-South links, such as Paris-Abidjan), several Administrations have since 1965 used automatic 96 baud error-correction devices associated with voice-frequency, multi-channel, frequency-shift telegraph systems with a channel spacing of 120 Hz and a frequency deviation of $\pm$ 35 Hz as in the Table of Report 42-1. The systems used were arranged for radio circuits.

Circuits thus set up are used in particular for transmission of cyphered messages and they have been working satisfactorily since they came into operation. Measurements conducted by the French Administration using error-correction over such a circuit during a period totalling more than 50 hours showed that values of efficiency factor were achieved in accordance with the attached curve.

This method of operation may suit quite a large number of links (e.g. Europe-West Africa links) and bearing in mind the constant search for the most rational use of the radio spectrum, it is concluded that as much information as possible should be obtained on the performance of circuits of this type, in particular concerning the undetected error-rate.

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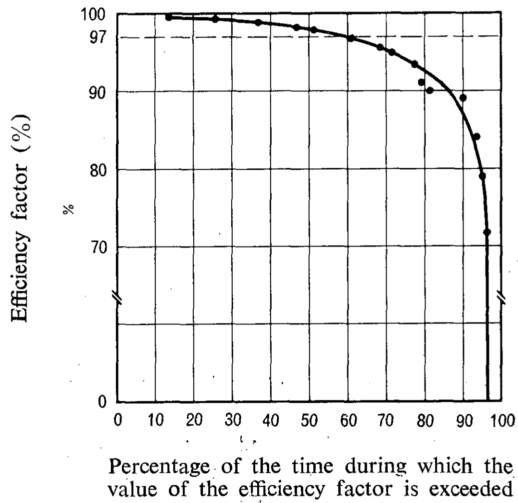
* This Report was adopted unanimously.



FIGURE

Distribution of efficiency factor in a 100 baud ARQ system with a 120Hz central frequency-spacing

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REPORT 348 *

SINGLE-CHANNEL SIMPLEX ARQ TELEGRAPH SYSTEM

(Study Programme 1A/III)

(1966)

1. Introduction

1.1 Study Programme 1A/III points out that regard should be given to new techniques and systems for application to the fixed services.

1.2 Large areas of the world do not yet have the facility of being connected to the international telegraph network, although they have a potential need for the exchange of messages by telegraph.

2. In the Annex to this Report, a type of telegraph system is described that might be quite useful in both the fixed and the mobile services for the realization of this facility.

2.1 It has been assumed that the amount of traffic to be dealt with will initially be small, and that usually the distances to be bridged will be great. A radio system might therefore best be suited to link an isolated station to one of the offices of the world-wide telegraph network. A suitable radio system could be a synchronous telegraph system making use of the well-known principle of automatic error-correction, by which the quality of the radio circuit is improved to a grade comparable with that of landline connections.

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* This Report was adopted unanimously.

2.2 It has also been assumed that localities of such isolated stations, and particularly mobile stations do not permit the simultaneous use of the radio transmitter and radio receiver.

2.3 Furthermore, it has been assumed that the power consumption of the equipment should be kept to a minimum.

2.4 To participate in the telex network the direction of traffic flow should be reversible instantly.

ANNEX

1. General

1.1 The system is a single channel ARQ system utilising the 7-unit error-detecting code laid down in the table of conversion.

1.2 Instead of duplex operation, alternate operation is used in the radio link (see § 2.2 of this Report).

1.3 The line terminal output uses the 5-unit start-stop code of the International Telegraph Alphabet No. 2 at a modulation rate of 50 bauds with a character cycle of 150 ms (see § 1.2 of this Report).

1.4 The modulation rate on the radio link is 100 bauds.

1.5 To provide an uninterrupted flow of start-stop signals during periods of no repetition and to permit the " information receiving station " (IRS) to confirm the good reception or to ask for repetition, the transmission is arranged in *blocks of three characters* (of 21 signal elements) *spaced by an adequate transmitter pause.*

1.6 Three " control " signals are employed on the return channel, two of which are used to inform the " information sending station " (ISS) whether the traffic flow is received correctly or not, the third control signal is needed to obtain the facility to change the direction of information flow.

2. Characteristics

2.1 *Arrangement of information in blocks with marked sequence*

When a circuit is established, the ISS commences to mark the transmission interval of successive blocks of information as interval 1 and interval 2. The third interval is marked in a similar way to interval 1, the fourth like interval 2, the fifth like interval 1, etc. This marking is continued as long as the station remains in the ISS position.

The sequence of reception at the IRS is marked in a similar way so long as unmutilated blocks are received. The sequence marking at the IRS is initially synchronized to the sequence marking at the ISS.

2.2 *Control signals*

These will be referred to as *ab*1, *ab*2, and *ab*3.

2.2.1 On the return channel the control signals *ab*1 and *ab*2 are alternately sent back to the ISS by the IRS.

The following rules apply to the signals transmitted on the return channel.

2.2.1.1 At reception of an information block the IRS transmits only one control signal on the return channel.

2.2.1.2 At reception of a mutilated block the same control signal is transmitted on the return channel as at the reception of the previous block. This means: repeat transmission of the last block.

2.2.1.3 At reception of an unmutilated block the IRS transmits the alternative of the control signal transmitted at the reception of the previous block. This means: continue by transmitting the next block. If the sequence numbering at the

IRS is 1, 2, 1, 2, etc., normally after interval 1, control signal *ab*2 is transmitted. After interval 2 this will be control signal *ab*1.

2.2.2 The control signal *ab*3 serves to reverse the direction of transmission of information between the two stations.

2.3 *Repetition procedure*

2.3.1 The ISS starts to repeat the transmission of the block previously transmitted when the control signal received does not fit to the interval of the local sequence that is just ending. So at a sequence numbering 1, 2, 1, 2, etc., no repetition action is initiated as long as control signal *ab*2 is received at the end of interval 1 and control signal *ab*1 at the end of interval 2.

2.3.2 When the control signal is not received or is received multilated at the ISS, this station will transmit three " signals repetition " in the next block instead of information.

2.3.3 The IRS will not print or pass a block when this contains a " signal repetition ", or when its content is mutilated. Moreover, on the return channel it retransmits the control signal transmitted last.

2.4 *Modulation rate*

On the radio circuit during the signal-on periods: 100 bauds. One block, consisting of three characters, is transmitted in 210 ms; an answer back signal in 70 ms.

At the start-stop terminals the interval between successive start elements will be 150 ms, so that the interval between successive blocks is 450 ms.

2.5 *Master and slave arrangement*

The station that initiates the establishment of the circuit becomes the master station and the station that has been called will be the slave station.

2.6 *Change of traffic flow direction*

2.6.1 When transmitting the block " signal β – signal α – signal β ", ISS urges the IRS to change to the information sending position.

2.6.2 To ensure that this is achieved both under favourable and unfavourable conditions of radio propagation the procedure is as follows:

2.6.2.1 The ISS, after having transmitted all its traffic, transmits the characters " figures-Z-B " (this is the " OVER " -signal: " figures – plus – interrogation ").
The IRS confirms the reception of these characters by transmitting the appropriate one of the control signals *ab*1 and *ab*2 on the return channel.

2.6.2.2 At the reception of the control signals, the ISS transmits a meaningless block (i.e. three signals β). The IRS, after unmutilated reception of this block, will transmit on the return channel the control signal *ab*3, indicating that since the reception of the previous characters it has noted these to be " figures-Z-B". In addition the line output will be switched to Z polarity.

2.6.2.3 At the reception of the control signal *ab*3, the ISS transmits the block " signal β – signal α – signal β ".
After unmutilated reception of this block the IRS switches over to the ISS-position and starts transmitting its first block, consisting of three " signals repetition ".

2.6.2.4 At the reception of the first " signal repetition ", the ISS switches over to the IRS-position and transmits the control signal " *ab*1 " during the interval that coincides with the position of the third character of a block, if this would have been transmitted.

2.6.2.5 Then the flow of information will start in the direction to which it has been changed over.

2.7 *(Selective) call signal*

A block consisting of three characters of which the first one is a " signal repetition ". The other two characters determine the station that is called.

2.8 *Phasing and rephasing*

2.8.1 *Phasing*

Stations in stand-by position are able to get into touch with each other. At the establishment of a circuit, the station that calls another station is in the master position. A station in stand-by position, and tuned to the transmitter frequency of the master station, will be alarmed by the reception of " signal repetition ". By means of a one-shot phasing procedure, this station's receiver is quickly phased to the master transmitter at the reception of the appropriate call signal. When phased, this station is in the slave position and starts transmitting control signals. The master receiver, also by means of a one-shot phasing procedure, phases quickly to the slave transmitter at the reception of a control signal by which the phasing procedure is accomplished.

TABLE OF CONVERSION

	International Code No. 2	7-unit code
(not used)	AAAAA	AZAZAZZ
E	ZAAAA	AZZAZAZ
Line feed	AZAAA	AAZZAZZ
Space	AAZAA	AAZZZAZ
Carriage return	AAAZA	AAAZZZZ
T	AAAAZ	AAZAZZZ
A	ZZAAA	ZZZAAAZ
I	AZZAA	ZAZZAAZ
N	AAZZA	ZAAZZAZ
O	AAAZZ	ZAAAZZZ
Z	ZAAAZ	ZZAAAZZ
S	ZAZAA	ZZAZAAZ
R	AZAZA	ZAZAZAZ
H	AAZAZ	ZAAZAZZ
D	ZAAZA	ZZAAZAZ
L	AZAAZ	ZAZAAZZ
U	ZZZAA	AZZZAAZ
C	AZZZA	ZAZZZAA
M	AAZZZ	ZAAZZZA
B	ZAAZZ	AZAAZZZ
W	ZZAAZ	ZZZAAZA
J	ZZAZA	ZZZAZAA
P	AZZAZ	ZAZZAZA
F	ZAZZA	ZZAZZAA
G	AZAZZ	ZAZAZZA
Y	ZAZAZ	ZZAZAZA
K	ZZZZA	AZZZZAA
V	AZZZZ	AAZZZZA
X	ZAZZZ	AZAZZZA
Figures	ZZAZZ	AZZAZZA
Q	ZZZAZ	AZZZAZA
Letters	ZZZZZ	AZAZZAZ
Signal repetition		AZZAAZZ
Signal α		ZZZZAAA
Signal β		ZZAAZZA
Control signals:		
*ab*1	(L)	ZAZAAZZ
*ab*2	(not used)	AZAZAZZ
*ab*3	(N)	ZAAZZAZ

2.8.2 *Rephasing*

If master station and slave station lose contact because of unfavourable reception conditions, the slave station will change over to the stand-by position, when after eight cycles of 450 ms no " signals repetition " or control signals have been received. The master station continues operation as ISS or IRS. As soon as reception conditions improve, the slave receiver phases, by means of a one-shot phasing action, to the " signals repetition " or to the control signals of the master station, after which rephasing is accomplished.

REPORT 349 *

SINGLE-CHANNEL RADIOTELEGRAPH SYSTEMS EMPLOYING FORWARD ERROR CORRECTION

(Study Programme 5A/III)

(1966)

1. Introduction

Contributions by Administrations to the XIth Plenary Assembly, Oslo, 1966, provide a basis for a preliminary report on the question of protection of single-channel radiotelegraph channels by means of methods of forward error-correcting. The experimental results reported in Docs. III/113 (XIII/82) and XIII/120, 1963-1966, are summarized, as well as the pertinent Docs. III/107 and III/117, 1963-1966.

2. Summary and discussion of reported results

Docs. XIII/82 (United Kingdom) and XIII/120 (Norway) both report on trials conducted with a system described by Keller [1]. This system uses a ten-unit self-checking code, a synchronous mode of transmission and is capable of correcting all single errors in the text and of detecting all double errors as well as most multiple errors introduced by the transmission path.

The ten-unit code consists of the 5 elements of the International Teleprinter Code No. 2 followed by 5 parity check elements. The 5 parity elements are either an erect or an inverse repetition of the information elements, depending on whether the Z count in the information elements is odd or even. Errors which are detected, but cannot be corrected, are indicated by the printing of " error " symbols, usually combination 31 or 32.

Transmission over the radio circuit is at modulation rates of 62·3, 68·5 or 102 bauds for teleprinter circuits operating at modulation rates of 45·45, 50 and 75 bauds respectively. At the lower modulation rates the system is capable of extension over the inland telegraph network using conventional 50-baud voice-frequency channels.

No special phasing signals are required, as the system is capable of fully automatic phasing during periods of traffic as well as during periods of idling.

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* This Report was adopted unanimously.

The system reported in Docs. XIII/82 and XIII/120 is currently in commercial service. Results obtained from field trials with this system are summarized in Table I.

In addition to these results, Doc. XIII/82 also reports that over the period of 7 August 1965 to 27 November 1965 a total number of 1099 data tapes, each containing between 1500 and 1800 characters, were transmitted from ships at sea to an office in London. Of these, 889 were accepted without need for later re-transmission (i.e. contained no errors).

It is further reported that tests between ship and shore stations with plain language messages, and ship-borne reception of Broadcast Services (e.g. press transmissions) were considered satisfactory, provided some measure of diversity in reception is used.

Doc. III/107 (Netherlands) proposes a single-channel error indicating system, operating at a modulation rate of 100 bauds, having to some extent capability for error-correction. The system uses a constant-ratio, seven-unit error detecting code, described in Doc. III/82, 1963-1966, but transmits each character twice with four other characters (equivalent to 280 ms) between the repetitions. If the reception of the first transmission of a character passes the constant-ratio check, it is accepted and passed to the printer through a delay circuit. If not accepted, the reception of the repeated transmission of the character is checked, and if accepted is passed direcly to the printer. If neither reception is found acceptable, a special " space " symbol is printed.

Transmission over the radio circuit is at a modulation rate of 100 bauds for teleprinter circuits operating at a modulation rate of 50 bauds.

Before starting the transmission of information, and in the idle time between successive messages or message blocks, the transmitting station emits idle time signals which are also used for phasing.

2.1 This system may be viewed in either of two ways:

2.1.1 *As a time-diversity system* with additional error detection capability. In this case, error performance (including detected but uncorrected errors) appears to be similar to the performance obtained by straight time-diversity such as reported by Lyons [2], provided that the separation of error bursts is not less than 420 ms. The additional four bits used in the system proposed in Doc. III/107 are used both for diversity selection and for error-detection;

2.1.2 *As a time-spread forward error-correcting system.* As such, the system is capable of correcting all single errors and most multiple errors, including error bursts of up to 280 ms, provided that the period between the occurrence of errors is at least 420 ms. It is further capable of detecting most uncorrectable errors.

2.2 System measurements have been made in the laboratory. The measurements concern the performance under varying signal-to-noise ratios for three cases, viz. a stable signal, a signal under flat fading conditions and a signal subject to selective fading. The results of the measurements are shown in Fig. 1 as curves for the probability for characters in error (p_c) in relation to the normalized signal-to-noise ratio (R), in accordance with the principles adopted in Report 195. The quasi fading-frequency was adjusted to approximately $N = 0{\cdot}5$ per second for these measurements.

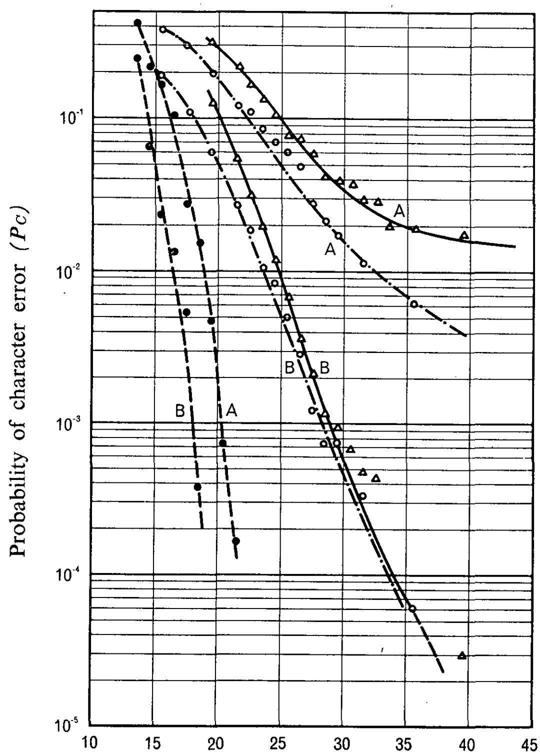
Note. – The curves of Fig. 1 do not take into account the 3 dB loss in normalized signal-to-noise ratio due to the higher modulation rate for time-diversity operation.

TABLE I

Summary of results

1	2	3	4	5	6	7
Document Ref.	Trial and circuit details	Characters passed	Errors detected and corrected	Detected but uncorrected error-rate	Residual uncorrected error-rate	Overall error-rate
XIII/82	Ship to shore, double-sideband transmission, single path reception	36 600	3·41 in 1000 characters	2·27 in 1000 characters	0·055 in 1000 characters	2·33 in 1000 characters
XIII/82	Ship to shore, single-sideband transmission, space diversity reception					0·84 in 1000 characters
XIII/120	Ship to shore, double-side-band transmission, space diversity reception (1), (2)	28 7776		1·26 per 1000 characters	0·56 per 1000 characters	1·82 per 1000 characters
XIII/120	Ship to shore, single-sideband transmission, space diversity reception (1)	42 952		1·42 per 1000 characters	0.54 per 1000 characters	1.96 per 1000 characters
XIII/120	Shore to ship, FSK transmission, single path reception	297 464		0·88 per 1000 characters	0·3 per 1000 characters	1·18 per 1000 characters
XIII/120	Shore to ship, FSK transmission, single path reception	54 508		1·76 per 1000 characters	0·31 per 1000 characters	2·07 per 1000 characters

(1) The distance between the two receiving antenna systems is rather small for space diversity operation.
(2) For these trials the ship transmitter was reduced to 1/4 of nominal power for technical reasons.



Normalized signal-to-noise ratio, R (dB)

(These curves do not take account of the 3 dB loss in normalized signal-to-noise ratio due to the higher modulation rate for the time-diversity case)

——●——	Stable signal
— . o . —	Flat fading
——Δ——	Selective fading
A:	Non-diversity reception
B:	Time-diversity reception

FIGURE 1

Doc. III/117 (U.S.A.) refers to four general types of forward error-correcting codes suitable for use on HF radio circuits. It further reports results from two field tests:

2.2.1 A system using a (15,10) block code (i.e. 10 information bits and 5 check bits per block), interleaved to provide 2 second burst error correction capability. This system was tested at teletype speeds over an HF link [3], and provided an improvement in the bit error-rate of about one order of magnitude when the uncorrected channel error-rate was 1×10^{-2}, and two orders of magnitude when it was 1×10^{-3};

2.2.2 A system using an adaptive convolutional code (Gallager code) with maximum burst error-correction capability of six seconds. A specific feature of this system is that the error-free interval, required for burst correction (guard space), is equal to the actual length of the burst plus about 20 bits, rather than equal to a fixed interval determined by its maximum burst correction capability.

2.3 A test is reported whereby this system was compared with the use of frequency diversity. Analysed in terms of blocks of about 3300 telegraph characters, it was found that, with the coding, over 90% of the blocks were error free, as compared with about 15% of the blocks when using diversity [4].

3. Conclusions

The present data available do not offer an adequate basis for comparison of the various systems described. Results from field trials are still limited and tests of different systems have not been conducted on the same basis or under similar conditions. It will be desirable to conduct further investigations, in particular trials which may provide a direct comparison between various systems.

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REPORT 350 *

SINGLE-CHANNEL DUPLEX ARQ TELEGRAPH SYSTEM

(1966)

1. Nowadays, multiplex systems effecting error-correction by automatic repetition (ARQ), are frequently used in the transmission of telegraph signals over radio circuits. The characteristics of such ARQ systems are laid down in Recommendation 342-1.

2. Where the volume of traffic does not justify the use of more than one channel, a single-channel ARQ system seems appropriate. A possible solution is to follow the principles laid down in Recommendation 342-1, Annex I, §§ 1, 2, 4, 6**, 7*** and 8 where they apply to single-channel operation.

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* This Report was adopted unanimously.

** For the purpose of this Report, Recommendation 342-1, § 6.1.2, Annex I should be read as: " After appropriate counts of *A* and *Z* elements . . . "

*** For the purpose of this Report modulation rates of 48, 72 and 96 bauds with transmission cycles of 145 $^{5}/_{6}$ 97 $^{2}/_{9}$ and 72 $^{11}/_{12}$ ms apply respectively.

REPORT 351 *

EFFICIENCY FACTOR

(Study Programme 17A/III)

(1966)

Docs. III/23 (Federal Republic of Germany) and III/106 (Rev. 1), pp. 3-16 (Companhia Portuguesa Radio Marconi), 1963-1966, report on tests which were carried out on short- as well as on long-range ARQ-radio circuits operated with a modulation rate 192 bauds, to analyse whether a correlation can be shown to exist between the results of the efficiency factor measurements and the assessment of the signal performance of the radio circuits.

Measurements of efficiency factor were made, using time intervals of 15 min (Doc. III/23) and intervals of 10 min, 1 min, and 20 s (Doc. III/106). Moreover, the mean value of the telegraph distortion and the relative field strength were recorded at the same time bases.

In addition, the following data were recorded in Doc. III/23: the operating frequencies, the variation of the geomagnetic field, the observed MUF and LUF values applicable to the circuits, the weekly and daily forecasts of MUF and LUF, the assessment of the quality of the circuits according to the SINPO code; and the following data were mentioned in Doc. III/106: the operating frequencies, the transmitting power, the class of emission, the transmitting and the receiving antennae gains, and the type of reception.

Identifiable disturbance due to causes other than the propagation medium were excluded from the results.

A critical study of results of the tests made shows that a correlation exists between the efficiency factor measured and telegraph distortion at the radio receiver output. On several circuits, where the efficiency factor was measured over periods of 15 min, a correlation coefficient of between 0·8 and 0·5 has been established [1].

In many, but not in all cases, a certain degree of correlation could be shown to exist between the results of efficiency factor measurements and the signal strength. However, in moments where a strong signal is disturbed by interference this correlation does not exist.

From this, it may be concluded that the measurement of telegraph distortion is the most suitable measurement to permit a rapid and continuous assessment of transmission quality, if reference cannot be made to efficiency factor measurements.

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* This Report was adopted unanimously.

REPORT 352 *

USE OF PRE-EMPHASIS AND DE-EMPHASIS FOR PHOTOTELEGRAPH TRANSMISSION OVER HF RADIO CIRCUITS

(Study Programme 1A/III)

(1966)

1. Introduction

The relationship between the picture density and the degree of modulation at present used concentrates the deterioration produced by noise at the darker end of the density range, whereas a linear relationship over the whole graduation range of picture density would distribute the effects of noise and so improve the picture quality. A further advantage would be to make the effect of frequency errors in transmission less noticeable.

To keep this relationship, a technique was introduced in Doc. III/31 (Japan), 1963-1966, which is described below.

2. Description of technique

The output of the photocell is proportional to the intensity of the reflected luminous flux, while the density of a picture is inversely proportional to the logarithm of the reflected flux.

The quality of the picture may be improved considerably when the signal is transmitted through a pre-emphasis network with a logarithmic characteristic, and received through a de-emphasis network with the inverse characteristic.

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REPORT 353 *

USE OF COMMON-FREQUENCY SYSTEMS ON INTERNATIONAL RADIOTELEPHONE CIRCUITS

(Question 9/III)

(1966)

1. Introduction

This Report deals with the technical characteristics required for common-frequency operation of radiotelephone circuits using single-sideband and independent-sideband emissions

* This Report was adopted unanimously.

2. The characteristics to be specified for radiotelephone systems using the principles of common-frequency operation

It is preferable to use the channel configurations shown in Recommendation 348-1 and only to shift the radiated frequency spectra between the two directions of transmission by about 150 Hz when using reduced carrier.

3. Minimum difference in level, at the input of the receiver, between the received signal from the distant station, and signals from the nearby transmitting station, to avoid interference between the wanted signal and that from the nearby transmitter operating at the same frequency

In the fixed service, the signal level received from the nearby transmitting station is usually lower than that from the distant station. However, if the signal from the nearby transmitting station exceeds the signal from the distant station by a considerable amount, the distortion products generated in the nearby transmitter will appear as crosstalk in the remaining channels of the distant multi-channel system. Tests have indicated that, where the nearby transmitter has an intermodulation level (see Recommendation 326-1 (of 30 dB, the signal from the nearby transmitter should not exceed that from the distant transmitter by more than 10 dB.

4. The extent to which the use of transmitting and receiving antennae with different characteristics reduce the possibilities of application of this technique

For point-to-point commercial communications, where the separation between transmitter and receiver of one terminal is approximately 30 km, it is not normally necessary to take such a problem into account.

5. The extent to which the possibilities of application of this technique are reduced by the presence of different noise levels at the receiving location

The effectiveness of the common-frequency technique is independent of the noise level at the receiving station.

6. Other factors to be taken into account when planning systems

6.1 *Characteristics of the carrier filter*

In several instances of the practical application of this type of operation the crystal filter used in the carrier branch amplifier for isolating the reduced carrier had a nominal bandwidth of 20 Hz. The actual characteristics of this filter are as follows:

Bandwidth (Hz)	Loss (dB)
±10	0±2
±20	10
±50	38
±70	50

In an effort to determine the effect that the carrier frequency received from the nearby transmitter might have on the receiver when it was receiving a signal from the distant transmitter, a test was made to determine the strength of signal required at various separations to make the receiver lose control.

The following data indicate that, if the two frequencies can be kept separate by 50 Hz or more, the near-end transmitter signal level can be considerably greater than that received from the distant transmitter.

Received frequency (MHz)	Separation frequency (Hz)	Signal generator input simulating distant transmitter (μV)	Signal generator input simulating near-end transmitter. Input varied from 0·5 μV to 50 mV
5	50	0·5	The a.f.c. was not affected up to a level of 50 mV
	100	0·5	
	200	0·5	
10	50	0·5	
	100	0·5	
	200	0·5	
15	50	0·5	
	100	0·5	
	200	0·5	
20	50	0·5	The a.f.c. was disturbed at 5 mV

A review of the above data shows that, if the frequency stabilities of the two transmitters are adequate to maintain a separation of greater than 50 Hz, there is no danger of the nearby transmitter taking control of the receiver away from the desired distant end signal. Assuming that the spacing is maintained between 50 and 250 Hz, the distortion products received from the near-end transmitter would be excessive long before its signal strength would be great enough to take control of the receiver.

6.2 *Frequency stability of the equipment*

To prevent an audible beat note in the channel adjacent to the reduced carrier, the frequencies of the two transmitters must not differ by more than 250 Hz, assuming that the pass band of the voice circuit is 250 to 3000 Hz. At the same time, because of the characteristic of the carrier filter, the frequency separation must be 50 Hz or more. From this we arrive at the most desirable separation of 150 Hz. This will allow a deviation of ± 100 Hz without exceeding the permissible limits, and is well within the capabilities of modern equipments, even at the highest frequencies.

7. Practical results

A number of systems operating on this basis have been in service since 1951. The experience from this operation has shown that radiotelephone systems using terminals having VODAS equipment will operate successfully on a common-frequency basis. Based on this experience, and the tests noted above, the Annex summarizes the several methods of operation with reduced and suppressed carrier. The left column lists the important characteristics which need to be defined for use of common-frequency systems on radiotelephone circuits, and the right column contains associated definitions and remarks which have resulted from the above tests.

ANNEX

1. Reduced carrier multi-channel operation

Criteria	Remarks
1.1 *Recommendation 335-1.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-1.	The equipments used in the system described above generally agree with the characteristics specified in this Recommendation.
1.2 *Level of signal received from local transmitter.* Important characteristics include physical separation between local receiving and transmitting stations, frequency of operation, physical terrain (hills, etc.), antenna patterns, antenna radiation efficiency, transmitting power, etc.	The physical separation between local receiving and transmitting stations must be great enough that the carrier signal level from the nearby transmitter will normally be less than the signal received from the distant transmitter and will rarely exceed it by as much as 10 dB. The use of transmitting and receiving antennae of differing characteristics will affect this type of operation only to the extent that they influence the strength of the signal received at the local receiver from the local transmitter.
1.3 *Mode of operation.* Reversible simplex operation.	VODAS equipment used on each voice circuit.
1.4 *Intermodulation distortion at the transmitter.*	The intermodulation level (Recommendation 326-1) should be lower then − 30 dB.
1.5 *Frequency stability of the transmitter*	Transmitter frequencies must be sufficiently stable to maintain a space of 150 ± 100 Hz between transmitted carriers.
1.6 *Bandwidth of a.f.c. carrier filter*	The carrier filter should have an attenuation of approximately 40 dB at the ± 50 Hz points.

2. Suppressed carrier multi-channel operation

Criteria	Remarks
2.1 *Recommendation 335-1.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-1.	See Recommendation 335-1.
2.2 *Level of signal received from local transmitter.* Important characteristics include physical separation between local receiving and transmitting stations, frequency of operation, physical terrain (hills, etc.), antenna patterns, antenna radiation efficiency, transmitter power, etc.	The physical separation between local receiving and transmitting stations must be sufficiently great, that the signal level from the nearby transmitter will normally be less than the signal received from the distant transmitter and will rarely exceed it by as much as 10 dB. The use of transmitting and receiving antennae of differing characteristics will affect this type of operation only to the extent that they influence the strength of the signal received at the local receiver from the local transmitter.
2.3 *Mode of operation.* Reversible simplex operation.	VODAS equipment used on each voice circuit.
2.4 *Distortion at the transmitter.*	The intermodulation level (Recommendation 326-1) should be lower than −30 dB.
2.5 *Frequency stability of receiver and transmitter.*	Transmitter and receiver must be sufficiently stable to maintain an overall frequency difference not exceeding 20 Hz for speech.

3. Suppressed carrier, single-channel operation

Criteria	*Remarks*
3.1 *Recommendation 335-1.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-1.	See Recommendation 335-1.
3.2 *Level of signal received from local transmitter.* Important characteristics include physical separation between local receiving and transmitting stations, frequency of operation, physical terrain (hills, etc.), antenna patterns, antenna radiation efficiency, transmitter power, etc.	For single-channel operation, the physical separation between the local receiving and transmitting stations must be great enough, that the level of residual noise at the receiver in the desired sideband is not increased by more than 1 dB when the transmitter power amplifier is operating normally but with no modulation applied. (Under this condition, the transmitter is producing broadband noise from the exciter and driver which can, if sufficiently high, interfere with the signal received from the distant station. See § 6 below).
3.3 *Mode of operation.* Reversible simplex operation	VODAS equipment used on the voice circuit.
3.4 *Transmitter distortion.*	The intermodulation level (Recommendation 326-1) of the transmitters should be lower than − 30 dB.
3.5 *Frequency stability of receiver and transmitter.*	Transmitter and receiver must be sufficiently stable to maintain an overall frequency difference not exceeding 20 Hz.
3.6 *Residual noise level at the transmitter.*	The residual-sideband noise level should not exceed − 56 dB relative to the peak envelope power.
3.7 *Blocking characteristics of the receiver.*	The receiver blocking characteristics must be such that the receiver will recover from a severe overload in less than 0·1 s if the front end of the receiver is not desensitized during the period of transmission from the local transmitter. (In this case, the local transmitter and receiver can be much closer together because there is no a.f.c. problem, only problems of interference and blocking remain. In some cases, the two may be co-located. The receiver can be left operative, during the period of transmission by the local transmitter, if it can receive a signal from the distant transmitter immediately after the local transmitter has ceased operation).

REPORT 354 *

AN IMPROVED TRANSMISSION SYSTEM FOR USE OVER HF RADIOTELEPHONE CIRCUITS

(Question 13/III)

(1966)

1. Introduction

Terminal apparatus currently employed on HF radiotelephone circuits includes constant-volume amplifiers (c.v.a.) and singing suppressors in each speech channel. The transmit c.v.a. performs its design function of maintaining a sensibly constant mean speech level at the transmitter input regardless of talker level but, because of the inherent high peak-to-mean power ratio of speech, the transmitter inevitably works well below its maximum power rating for a large percentage of time. The receive c.v.a. reduces the speech level variations caused by fading, but cannot discriminate against atmospheric noise and interferences and will in fact accentuate them if their level is permitted to exceed the c.v.a. input threshold. The singing suppressors are susceptible to misoperation by high levels of received noise, and clipping or suppression of speech in the transmit channel can result. Even under good circuit conditions the use of singing suppressors operates against a smooth flow of conversation.

In line transmission the effects of noise can be reduced by the use of a compandor, but such a system will function correctly only if the loss remains constant between the compressor output and the expandor input. This requirement has so far precluded the application of compandor techniques to HF radio circuits. If, however, the information concerning the degree of compression introduced at the transmitting end can be accurately conveyed to the expandor at the receiving end (e.g. by the use of a separate information channel), then such a system could be made to operate satisfactorily. The use of a separate control signal will, moreover, remove the usual restriction on the degree of compression; greater compression can be employed, resulting in more effective use of the power-handling capability of the transmitter.**

The " Lincompex " (Linked Compressor and Expandor) system has been developed from this concept. The speech is compressed to a sensibly constant amplitude and the compressor control current is utilized to frequency-modulate an oscillator in a separate control channel. The speech channel, which contains virtually only the frequency information of the speech, and the control signal channel which contains the speech amplitude information, are combined for transmission over a 3 kHz channel. As each speech syllable is individually compressed the transmitter is more effectively loaded than in current practice. On reception both the speech and the control signals are amplified to constant level, the demodulated control signal being used to determine the expandor gain and thus restore the original amplitude variations to the speech signal. Because the output level at the receiving end depends solely on the frequency of the control signal, which is itself directly related to

* This Report was adopted unanimously.

** The earliest known reference to the use of a separate control channel in this manner is an article by P. Deman, " Circuits téléphoniques sur liaisons de faible qualité ". L'Onde Electrique, **49**, 656 (July/August, 1961).

the input level at the transmitting end, the overall system loss or gain can be maintained at a constant value. Operation with a slight loss (two-wire to two-wire) permits singing suppressors to be discarded, although echo suppressors will be needed, as on long-line circuits.

2. Outline description of Lincompex system

A simplified block schematic of a terminal equipment is shown in Fig. 1.

2.1 *Transmitting side*

The speech signal, after passing through the echo-suppressor (of the type normally used on line circuits) traverses two paths. One path leads to the amplitude assessor, the sole function of which is to generate a d.c. control signal corresponding to the speech amplitude. Over the other path, the speech signal passes through a delay unit (approximately 4 ms) and thence to the compressors. Two compressors are used in tandem, the variable-loss networks being energised by the d.c. control signal instead of by their individual outputs. The separate derivation of the control signal, together with the delay unit, ensures that the speech signal and the control signal are so synchronized that precursive peaks at the compressor output, due to a suddenly applied signal, are minimized. This arrangement of compressors can produce, in the steady state of the signal, a substantially constant output over an input signal level range of approximately 50 dB.

The d.c. control signal, in addition to determining the compressor gain, modulates the frequency of an oscillator so as to produce a 2 Hz frequency change for each 1 dB change

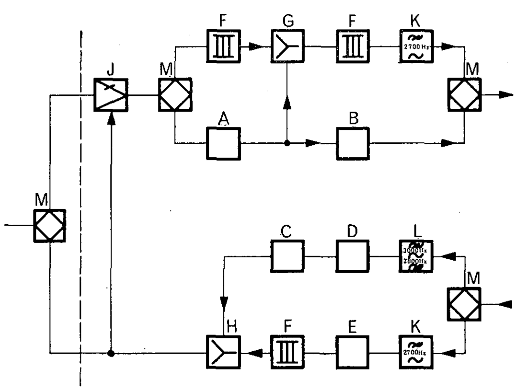

FIGURE 1

Block-schematic of Lincompex system

A: Amplitude assessor
B: Frequency-modulated oscillator
C: Frequency discriminator
D: Limiter-amplifier
E: Constant-volume amplifier (fading regulator)
F: Delay network
G: Compressor
H: Expandor
J: Half echo-suppressor
K: Low-pass filter (2700 Hz)
L: Band-pass filter (3000-2800 Hz)
M: Hybrid transformer

in level at the input to the amplitude assessor. The approximate frequency limits are 2950 Hz for no input and 2850 Hz for the maximum input to the amplitude assessor. The circuit constants of the assessor and oscillator are such that, under dynamic conditions, the spectrum of the control signal may extend from 2810 to 2990 Hz.

The compressed signal in the speech path is subjected to a time delay (discussed later) and then band-limited in a 2700 Hz low-pass filter. Finally, the compressed speech and the control tone are combined to form a composite signal in the band 250-3000 Hz suitable for application to a radio transmitter.

2.2 *Receiving side*

The received signal is divided between two paths, the speech signal being selected in a 2700 Hz low-pass filter and the control signal in a 2810-2990 Hz band-pass filter. Level variations of the speech signal due to fading are removed by amplification to a constant level in a specially designed quick-acting c.v.a. (fading regulator). The control tone is limited and applied to a frequency discriminator to recover the d.c. control signal. After suitable delay the speech signal is applied to the expandors which, under the influence of the control signal, perform a complementary function to that of the transmitting-end compressors to restore the amplitude variations in the speech.

2.3 *Transmission time equalization*

The necessity for the pre-compressor delay has already been explained. Additionally, however, time equalization may be required in the speech path to compensate for the delay inherent in the control path due to the narrow-band filtering. Laboratory tests have shown that the omission of this equalization introduces some degradation of speech quality and causes severe distortion of signalling impulses. Although the control path delay occurs mainly at the receive terminal, the equalization is equally divided between the transmit and receive paths of each terminal. By adopting this arrangement the delay may conveniently be removed when it is not required, e.g. when 5-band privacy equipment, with its inherent delay, is in use.

3. Field trial

Experimental equipment, similar in principle to the Lincompex system described but differing in detail, has been tested operationally at the terminal stations of the London-New Delhi radio circuit. This circuit carries a three-channel telephone system and the performance of a Lincompex-equipped channel carrying public-service traffic has been compared with that of a conventionally-equipped channel. The Lincompex equipment and the conventional terminal were applied to the two inner channels of the radio system, the channels being interchanged at weekly intervals throughout most, but not all, of the 17-week trial period (December 1964-April 1965).

The Lincompex equipment gave consistently longer commercial time than the conventional equipment, the average daily commercial periods being 6·6 and 5·8 hours (14% increase) respectively during a 12-week period when channels were systematically interchanged, but taking the 17-week trial period as a whole, the corresponding figures were 6·2 and 5·2 hours (19% increase) per day.

Quite apart, however, from the extension of commercial circuit availability, a noteworthy feature was the greater potential call-handling capacity of the Lincompex channel due to the smoother flow of conversation, of operators and subscribers alike, which the omission of singing suppressors made possible. This was clearly demonstrated during a special 4-week service observation period when particular attention was paid to the quality of calls.

Of the observed calls, 70% were graded " excellent " or " good " on the Lincompex channel, the corresponding figure for similar gradings on the conventional channel being 58%. The improvements were particularly noticeable on transit calls extended over long-distance cable circuits.

ANNEX

1. Introduction

The function of the transmit compressors in the Lincompex system is to provide a sensibly constant output over a wide range of input levels. In an ideal circuit a constant level would be directly applied to the expandors, so in a practical radio circuit, level variations caused by fading have to be compensated by a constant volume amplifier (fading regulator) at the receive end of the circuit. The fading regulator employed in the Lincompex system is unlike conventional c.v.a.'s, which revert to zero gain for input levels below the threshold, in that its gain rises to a maximum in the absence of a signal and thus contributes additional gain in the overall speech path. To ensure that the system always works in a stable condition, in particular when there is no signal input, the controlled expandor loss must at all times exceed, by a small margin, the sum of the gains in the speech compressor and the fading regulator.

Practical design difficulties dictate a maximum control range of 60 dB and, since a fading regulator gain of 15-20 dB is customary, it follows that the compressor gain must not exceed 40 dB. For input levels below the compression range the compressor must therefore be arranged to operate as a linear amplifier, any level reductions being compensated by the fading regulator gain. The full improvement in signal-to-noise ratio will not, therefore, be achieved for input levels which fall into the linear part of the compressor range; existing systems also suffer degradation when the input signals fall below the range of the transmit c.v.a.

The system parameters to which equipment is currently being produced for an extensive field of the Lincompex system are set out below.

2. Speech path

2.1 *Compressor* (Controlled by amplitude assessor)	
Input levels between which the output is sensibly constant	– 4 to – 44 dBm (Note 1)
Linear range	below – 44 dBm
Time constant	18 to 20 ms
2.2 *Pre-compressor delay*	3.5 ms to 4.5 ms
2.3 *Low-pass filter*	Effectively limits speech band to 2700 Hz
2.4 *Constant volume amplifier* (Fading regulator)	
Input range	– 3 to – 27 dBm (Note 2)
Time constant	18 to 20 ms
2.5 *Expandors* (Controlled by the discriminator)	
Effective range of less variation	60 dB
Time constant	8 to 10 ms

3. Control path

3.1 *Amplitude assessor* (A self-controlled compressor)	
Compression law	2:1
Input levels over which the 2:1 law is obtained	– 4 to – 64 dBm (Note 1)
Time constant	18 to 20 ms
3.2 *FM oscillator* (Frequency controlled by amplitude assessor)	
Nominal centre frequency	2900 Hz
Maximum frequency deviation	± 60 Hz
Change of frequency per dB, change of level at the input of the amplitude assessor	2 Hz
Level at input of the amplitude assessor to produce nominal centre frequency	– 34 dBm
Direction of frequency change for an increase of level at the input to the amplitude assessor	Negative
Time constant	Approx. 4 ms
Output spectrum	Effectively limited to 2800 to 3000 Hz
3.3 *Limiter*	
Input range	– 8 to – 45 dBm (Note 2)
3.4 *Discriminator*	
Change of frequency at input to produce a level change of 1 dB at the output of the expandors	2 Hz

4. Transmission time equalization

Allowable overall difference of transmission time between the speech and the control paths	± 4 ms

Note 1. – This assumes speech levels varying between – 6 and – 45 dB relative to RTP at the two-wire input.

Note 2. – These levels are based on the assumptions that the median level of the received signal in the speech paths is – 10 dBm when a test tone within the compression range is applied at the speech input of the Lincompex equipment and that the level of the signal in the control channels is 5 dB lower.

REPORT 355 *

USE OF DIVERSITY ON INTERNATIONAL HF RADIOTELEPHONE CIRCUITS

(Question 13/III)

(1966)

1. Introduction

This Report describes tests of several diversity techniques for HF radiotelephone service, including wide spaced diversity, frequency diversity, and time diversity.

2. Wide space-diversity for voice operation

Recently, HF wide space-diversity tests using an experimental comparator to select the better of two overseas circuits have been performed. Briefly, this comparator measures the received noise and/or interference during outgoing speech (under control of the VODAS), and switches its output to the quieter of the two circuits. The tests were made to determine the transmission improvement that can be obtained by using such a device to select the better output from two widely spaced receivers.

These tests were made using similar radio receivers located about 135 km (85 miles) apart. The receivers were adjusted to have as nearly as possible the same performance and they were tuned to an idle channel on the same overseas transmitter. The output of both the accepted and rejected circuits were recorded on a dual pen recorder which was equipped also with an event recording pen to give a continuous record of the switch position. At all times the receiver with noise peaks, occasioned by radio fading at the receiver sites, was rejected by the diversity switch.

Data from these tapes were selected on a time basis using samples of one second duration as the basic units. Fig. 1 shows the received noise from both the accepted and the rejected receivers plotted against the percentage of the total time that levels were equal to or greater than the absolute values of the ordinate. These curves were plotted from 21 600 one-second samples when noise alone was controlling the switching. The median improvement as read from the curve is greater than 3 dB and for 1 % of the total time, during the deep fading periods, the improvement is about 7 dB. As expected no improvement is indicated at noise levels below 35 dBrn where the noise is inaudible.

The diversity switch control circuit (comparator and switch) has two inputs with a single output. The two input signals are compared and the quieter signal is automatically switched to the output. Monitoring jacks are provided for both the accepted channel and the rejected channel. Provision is made to monitor the incoming signals under two conditions; the first for monitoring only during the periods when the VODAS relay action indicates that there is no incoming speech, the second, which was used in these tests, provides for continuously monitoring an idle channel, by simulating continuous VODAS operation. The dynamic range of the switch is from 30 dBrn (practically inaudible) to 85 dBrn (objectionable) when measured at either of the comparator inputs with 3 kHz flat weighting. Attenuators were inserted ahead of the switch inputs, so that cases of extreme noise levels could be brought

* This Report was adopted unanimously.

within the operating range of the switch. A built-in delay prevents the switch from operating on occasional impulse noise peaks but discriminates against the characteristic noise caused by electrical storms.

There is a lack of correlation in the fading rates of HF signals at receiving stations separated by a number of miles. No effort has been made to determine the minimum distance at which this lack of correlation is sufficient to permit diversity operation. The improvement obtained through use of duplicate receiving and connecting wire-line facilities is sufficient to justify its use on important radio systems.

3. Time-diversity of voice operation

The new time-diversity system for radiotelephone transmissions described below is suitable for push-to-talk type operation, broadcast relay, and other similar services but, since the system introduces a time delay of up to a second, it is not suitable for normal telephone service where almost instantaneous replies are required. The system relies upon the fact that there is appreciable frequency redundancy in speech waves, so that if one frequency segment is lost the other segments will normally carry the intelligence.

The equipment used at the transmitting site separates the speech wave into a number of small frequency bands; for example, the centre frequencies of the filters may be at 360, 570, 900, 1430, 2270, 3600 Hz. The output of the first filter is fed directly to the transmitter, the second filter to a time delay of one-half second, a third filter fed to a time delay of one second, the fourth filter is fed directly to the transmitter, etc. as shown in Fig. 3.

The output of the receiver is fed to similar equipment, but in this case the frequency segments that are not delayed at the transmitter are delayed a full second at the receiver and the frequency segments that are delayed one-half second are delayed an additional one-half second at the receiver and finally the segments that are delayed a full second at the transmitter base are fed undelayed to the combiner network at the receiver . Thus, a natural sounding wave delayed one second results.

The system has three desirable effects:

- if a fade lasts for less than a second, the bulk of the highly redundant speech wave will be received;
- there is a 6 to 7 dB measured reduction in peak level for a constant average level. The reason for this improvement is that the peaks of the voice wave form are reduced relative to the average level. The energy is more evenly distributed because of the time delays;
- the technique provides privacy in that the reception of the signal requires decoding equipment. However, if time delays of 1·5 to 2 s are used the privacy effect is for all practical purposes eliminated. Experiments with this system indicate that to achieve the reduction in peak-to-average levels a time delay of at least 0·1 s is required. The amount of time delay required for achieving diversity gain is, of course, a function of the fading rate and it would appear that a delay of at least 1 s is desirable if one wishes to achieve a substantial reduction in the effects of fading.

4. Audio-frequency band-splitting combiner for space diversity

In this system a combiner splits each of the two receiver audio-frequency bands into three segments. Each segment is processed through two band-pass filters, a comparator and two amplifiers.

The output signals from the bandpass filters are applied to the amplifiers and also to the comparator circuit. The comparator converts the a.c. input signals into two d.c. voltages of opposite polarity. These voltages are compared on a continuous basis to determine which is the stronger signal.

The comparison output drives a differential control amplifier. The type of variable-gain action obtained prevents any thumps, clicks and transients of the signal applied to the two filters for that segment. However, should the signal at Filter 1 fade by 2 dB or more, compared with the signal at Filter 2, the selected output signal (signal at Filter 2) will be at least 20 dB greater than the weaker signal (signal at Filter 1).

The outputs from the three segments are combined in linear addition to reproduce the audio spectrum. The audio output response is improved over the non-diversity case for any amount of signal fading.

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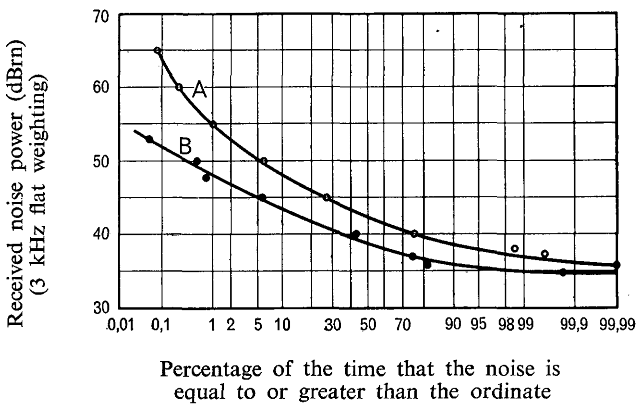


Figure 1

Wide-spaced diversity, 16 430 kHz, June 11 to 13, 1962, 21 600 samples
Noise alone was switching criterion
Receiving stations at Manachawkin and Netcong, NJ

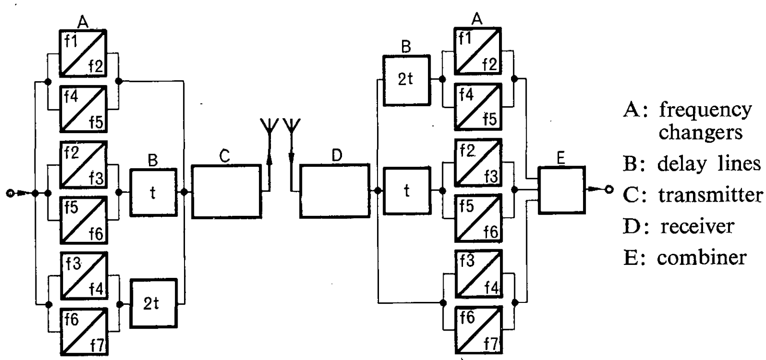


Figure 2

Simplified block diagram of Echoplex

REPORT 356 *

USE OF DIRECTIONAL ANTENNAE IN THE BAND 4 TO 28 MHz

(Recommendation 162-1)

(1966)

1. Introduction

Question 10/III poses the problem of specifying reasonable standards for the directivity of antennae in the various types of radio service, and for various distances, in the bands between 4 and 28 MHz with due regard to economy of cost. This Report is mainly concerned with point-to-point circuits longer than 4000 km but, with suitable modification, could be applied to shorter range circuits. The technique discussed requires a knowledge of the gain of the antenna under consideration and the angular widths in zenith and azimuth of its main beam of radiation. With this information a directivity factor is derived which, used in conjunction with certain other factors, e.g. transmitter power and provision cost, may be used to assess the suitability of an antenna for any particular application.

2. Proposition

An antenna possessing a given directive gain which radiated all its power in a single beam could be regarded as having the best attainable performance of its class. Communication systems using such antennae for emission and reception could operate on a common frequency with a given spatial distribution without risk of mutual interference, the only condition being that each receiving antenna should " see " only the wanted transmitting antenna. With such an ideal arrangement the number of systems sharing the same frequency would increase as a function of the gain of the antennae because of their smaller angular beamwidth.

By making certain simplifying but justifiable assumptions, it can be shown that to a high degree of approximation there is a fixed relationship between the directive gain (relative to an isotropic radiator) and the angular widths of this single beam (to the null) as follows:

$$G = P_o/P = 32\pi^2/(\pi^2 - 4)\ \theta_o\, \varphi_o = K/\theta_o\, \varphi_o \qquad (1)$$

(θ_o and φ_o are the horizontal and vertical angular widths respectively, in radians and P, P_o are the total powers radiated from the ideal antenna and the isotropic radiator respectively to produce the same field in the desired direction).

Practical antennae fall some way short of this ideal in that a proportion of the power is radiated (or received)in directions other than in the main beam.

If the directive gain of such an antenna is G' and the widths of its main beam are θ_o', φ_o', then from (1), the power radiated in the main beam:

$$P' = P\theta_o'\varphi_o'/K \qquad (2)$$

* This Report was adopted unanimously.

If this represents a fraction, q of the total radiated power,

$$G' = P_{oq}/P' = K_q/\theta_o'\varphi_o' \quad (3)$$

or $$q = G'\theta_o'\varphi_o'/K \quad (4)$$

Thus, from the measured or computed characteristics of an antenna it is possible to determine its radiation efficiency, i.e. the fraction of the total radiated power that is directed in the main beam.

The power radiated outside the main beam of a transmitting antenna which is liable to set up interfering signals is given by:

$$P_o\,(1-q)/G'$$

If this were distributed evenly over the residual hemisphere outside the lunar arc θ_o', the average power flux would be

$$P_o\,(1-q)/(2\pi-\theta_o')\,G'$$

Since the maximum flux in the main beam is $P_o/4\pi$, we can write

$$\frac{\text{Maximum useful signal power flux}}{\text{Average interfering signal power flux}} = \frac{G'(2\pi-\theta_o')}{(1-q)\,4\pi} \quad (5)$$

As is well known, the spatial distribution of flux outside the main beam will vary widely and values considerably in excess of the average will be found. It would seem appropriate to express this as a probability distribution in such a way that its effect in degrading the signal-to-interference ratio appears as a term in the directivity factor of the antenna. To do this would require a knowledge of the minor beam flux distributions of a large sample of practical antennae and because insufficient information of this nature is available an alternative approach must be adopted. The method used is to derive an antenna directivity factor based on the assumption that all the misdirected power appears as a number of equi-amplitude secondary beams and to apply an adjustment when individual secondary beam amplitudes are likely to be significant to a particular problem, e.g. frequency sharing studies.

If the same power distribution (cosine-squared) as that asuumed for the main beam is used then, for the secondary beams,

$$\left(\frac{F\ \text{max}}{F\ \text{average}}\right)^2 = \frac{2\pi^2}{\pi^2-4} = 3{\cdot}41\ (5{\cdot}3\ \text{dB})$$

and we can then write,

$$\frac{\text{Maximum useful signal power flux}}{\text{Maximum interfering signal power flux}} = \frac{G'\,(2\pi-\theta_o')}{(1-q)\,4\pi \times 3{\cdot}41} \quad (6)$$

One further modification to the formula is necessary to take account of what has been called the " propagation match " of the antenna: various studies have shown that for long distances (>4000 km), circuit performance improves as the vertical angle of the main beam maximum of the antenna is reduced.

A weighting factor (appropriate for vertical launching angles between about 5° and 25°) allows for this effect and the equation for the antenna directivity factor becomes,

$$M = \frac{G' \ (2\pi - \theta_o')}{(1-q)\, 4\pi \times 3{\cdot}41} \cdot \frac{10}{\Delta m}$$

For distances less than 4000 km, this factor may be omitted and instead the height of the antenna chosen to match the propagation conditions over the route;

and expressing θ_o', φ_o' in degrees,

$$M = \frac{G' \ (360 - \theta_o')}{245{\cdot}6 \ \Delta m \, (1-q)} \tag{7}$$

where $q = \dfrac{G' \theta_o' \varphi_o'}{176\ 600}$

G' = directivity gain of antenna expressed relative to an isotropic radiator (expressed as a ratio unless otherwise stated),

θ_o' = horizontal angular width of main beam in degrees (to first minimum points),

φ_o' = vertical angular width of main beam in degrees (to first minimum points),

Δm = vertical angle of main beam maximum (degrees).

3. Application

M values for a number of actual antennae of various types are plotted in Fig. 1. The main beam performances of all but three of the antennae considered had been explored using airborne equipment and for these, measured gains (power gains) were available; these were translated to directive gains for application in equation (7). The main beam performances of the three exceptions (single rhombic antennae at 4, 6 and 8 MHz) were computed, allowance being made for the reduction in directive gain due to non-uniform current in the antenna wires.

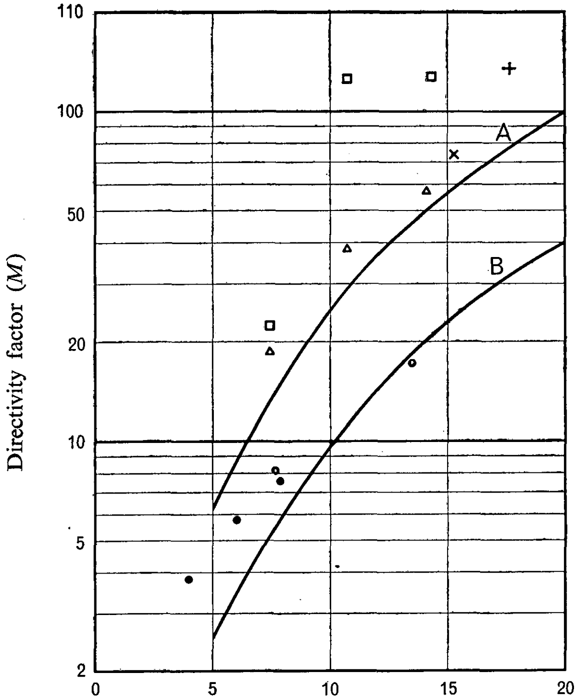
Although interpretation of the results plotted in Fig. 1 is made difficult by the dearth of suitable data, the plot provides an indication of variation with frequency of the main beam performance of single antennae and antenna arrays. Curves, which it is considered represent reasonable standards of performance for these two classes of antenna have been drawn on the diagram. The lower curve (labelled minimum standard antenna) is a best fit to the available experimental data and may be expressed as $M = 0{\cdot}1 f^2$. This is considered to be representative of the standard of performance to be expected from well-designed single rhombic antennae operated within a frequency band in which the ratio of highest to lowest frequency does not exceed 2.

The upper curve (Economic reference antenna) which may be similarly expressed as $M = 0{\cdot}25\ f^2$ represents a standard of performance which will normally only be achieved with antenna arrays. This higher standard necessarily involves a proportionally greater expenditure on antenna plant but, as has been proposed elsewhere *, some increase above the current level of expenditure can be economically justified.

For frequency planning and other allied studies the occurrence frequencies of secondary beams having amplitudes greater than the equi-amplitude crest value may be important. Within the range M values considered the results of the measurements made on practical antennae indicate that not more than 10% of the secondary beams will exceed the equi-

* Survey of aerials and aerial distribution techniques in the HF fixed service D. E. Watt-Carter and S. G. Young. *Proc. I.E.E.*, Vol. 110, 9 (September, 1963).

amplitude crest value by 6 dB. Thus, for an antenna having an M value of 40, the ratio of the levels of the main-beam intensity and the higher secondary-beam intensity would be 10 dB. These secondary beams will usually be adjacent to the main beam.



Frequency (MHz)

Curve A: Economic reference antenna

Curve B: Minimum standard antenna

- ● Single rhombic antennae (CCIR antenna diagrams Figs. 32*a*, 33*a*, 35*a*)
- ○ Single rhombic antenna 425′/65°/150′
- △ 2-stacked rhombic array
- □ 2-stacked 2-interlaced rhombic array
- × Dipole array HR 4/4/1·0
- + Dipole array HR 8/4/0·5

FIGURE 1

Antenna directivity-factor based on the measured characteristics of HF antennae

REPORT 357 *

OPERATIONAL IONOSPHERIC SOUNDING AT OBLIQUE INCIDENCE

(Study Programme 20A/III)

(1966)

1. Introduction

Study of the results from frequency soundings have led a number of workers [1, 2, 3] to suggest that frequency sounding equipment could be used in parallel with a communications system to determine optimum, short-term operating frequencies. A number of studies have now been carried out [4, 5] and are being considered, which are designed to determine the improvements that can be achieved from the use of sounding information.

2. Operational problems encountered using frequency sounding systems

Experiments carried out so far using ionospheric sounding at oblique incidence disclose a number of problems.

2.1 The differences in sensitivity between communication and sounding equipment. To secure valid information of use to communicators this difference must be allowed for.

2.2 The inaccuracies in sounder predictions which result from sounding over an ionospheric path separated from the communication path and in the opposite direction of a non-reciprocal path. Preliminary studies [6] suggest that for a separation of 16 km these differences can be reduced to less than 10 dB by averaging sounding information over a number of short-term fading correlation periods.

2.3 The differing performance of the sounder and communication antenna systems.

2.4 The differing performance of the sounder and communication equipment in the presence of interference.

3. Types of sounding systems

There are a number of types of oblique incidence sounding systems but two in particular may be considered for use in connection with operational circuits.

3.1 *The locally operated, independent, or semi-independent channel sampling system*

A particular service adopting a channel sampling system could use its complement of allocated frequencies for both frequency sounding and communications on a time or frequency-shared basis. The total bandwidth occupied by the emission would therefore be relatively narrow, and the number of frequencies limited. The sounding and communication system could be co-sited, or not widely separated. This system essentially avoids the problems mentioned in § 2.2 with the penalty of reduced propagation information, and hence reduced ability to predict propagation changes.

* This Report was adopted unanimously.

3.2 *The common-user system*

Stations participating in a common-user system would receive directly, or indirectly, statistical propagation information appropriate to their communications path for time periods of a few minutes to many hours. Prediction of statistical propagation characteristics requires reliable propagation mode information, which can be obtained using a large number of sounding frequency channels (i.e. 40-80) for high resolution across the entire HF band, and a wide sounding signal bandwidth (i.e. 5-10 kHz) for propagation mode resolution. The operational and interference problems raised by the implementation of such a system for wide-scale use require technical consideration at the international level at the earliest possible time.

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REPORT 413

OPERATING NOISE-THRESHOLD OF A RADIO RECEIVING SYSTEM

REPORT 414

EFFICIENT USE OF THE RADIO-FREQUENCY SPECTRUM

REPORT 415

MODELS OF PHASE-INTERFERENCE FADING FOR USE IN CONNECTION WITH STUDIES OF THE EFFICIENT USE OF THE RADIO-FREQUENCY SPECTRUM

(1966)

In accordance with a decision of the XIth Plenary Assembly these three Reports will be published separately.

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STUDY GROUP III

(Fixed service systems)

Terms of reference:

1. To study questions relating to complete systems for the fixed and allied services and terminal equipment associated therewith (excluding radio-relay systems). Systems using the so-called ionospheric-scatter mode of propagation, even when working at frequencies above 30 MHz, are included.

2. To study the practical application of communication theory.

Chairman: Dr. H. C. A. van Duuren (Netherlands)
Vice-Chairman: Dr. S. Aritake (Japan)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP III

1. The scope of the work of Study Group III covers the study of world-wide radiocommunications in the fixed services, for which the HF (decametric) band is mainly used. The study aims at recommending methods of two-day radiocommunication by means of telephony, telegraphy and facsimile. The application of such methods will enable Administrations to interconnect their landline networks to the world-wide communication network through radio links. The Recommendations of the Study Group contain the best solutions agreed upon internationally for obtaining commercial quality.

2. Recommendations 75, 100, 335–1, 336–1, 338–1, 348–1 and 349–1 contain information to carry telephony over radio links by the application of single-sideband and independent-sideband systems (information concerning: system bandwidth and frequency tolerances, channel arrangements, privacy equipment and echo suppression). Studies have been started on systems having improved bandwidth utilization (Question 9/III and Report 353) and on improvements obtainable in the quality of radiotelephone transmission (Question 13/III; Reports 354 and 355).

3. Recommendations 106, 246–1, 338–1, 342–1, 345, 346, 347, 349–1 and 436 deal with communication by means of telegraphy (information concerning: channel bandwidth, channel arrangement and frequency tolerances, operation on FSK and twinplex channel and on ARQ-systems, classification of channels and definitions on the telegraphic distortion).
The interest in further study of telegraph transmission is reflected in Questions 2/III, 6/III, 7/III, 8/III, 12/III and 15/III and in Study Programmes 8A/III and 17A/III. Reports 19–1, 42–1, 345, 346 and 347 contain observations and useful data on telegraph channels capable of transmitting telegraph signals at a high transmission density. The work done on telegraph systems giving protection against errors is intended partly to investigate the variation in time of error-rate for synchronous systems in general (Report 200–1) and to study the behaviour of the efficiency of ARQ-circuits (Report 351) (see also § 9).

4. Recommendations 343–1 and 344–1 deal with facsimile transmissions of meteorological charts and with the transmission of phototelegraphy on radio links connected to the

landline network. The study of remote control signals for facsimile transmission over radio links is covered by Report 201-1. Data on the improvement obtainable by the application of pre-emphasis for phototelegraph transmission are given in Report 352.

5. Operation on radio links is impaired by fading and noise under unfavourable conditions of radio propagation, or by interference from unwanted emissions. The study of the difficulties encountered and of measures to increase the time operational quality for the various systems is covered mainly by Questions 1/III and 11/III and by Study Programme 1A/III. This study is continued and the fixing of protection ratios against unwanted interfering emissions is in progress in cooperation with the I.F.R.B. (Report 197-1). Some information is available in Recommendations 240, 339-1 and 340.
The study of the techniques of oblique-incidence ionospheric sounding has been opened for operational purposes (Study Programme 20A/III and Report 357). Research work on propagation effects has been recorded in Reports 109-1, 111 and 203.
The International Working Party established to reach the objectives of Resolution 1-1, has produced three Reports on procedures, definitions and fading models related to the study of an improved use of the radio-frequency spectrum (Reports 413, 414 and 415). These Reports will be issued separately from the series of the XIth Plenary Assembly of the C.C.I.R.
Question 14/III asks for the features of automatically controlled radio systems which require cooperation between Administrations.

6. The use of the radio path will be improved by the application of directional antennae. Recommendation 341 gives definitions on transmission gain and loss, and Report 112 shows the application of these concepts. Results of the study on the directivity of antennae at great distances are shown in Report 109-1. Further characteristics of antennae are defined in Recommendation 162-1 and discussed in Report 356.

7. Communication theory gives the basis for a better understanding of system performance. Therefore developments in communication theory may lead to the improvement of systems. Question 5/III and Study Programme 5A/III deal with communication theory. Report 196-1 shows some applications. Practical applications were discussed by the Study Group in the field of synchronous telegraphy (see §§ 3 and 4).
The Study Group uses the binary information unit (bit) as a standard for comparing the performance of telegraph systems (Recommendation 166-1) and uses the normalized signal-to-noise ratio for comparing radiotelegraph channels (Report 195).

8. Cooperation with the C.C.I.T.T. resulted in Recommendation 335-1 (telephony), Recommendation 344-1 (phototelegraphy), Recommendations 342-1 and 345, Reports 19-1 and 351 (telegraphy).
This cooperation is continued in the study laid down in Study Programme 18A/III and Question 15/III (efficiency factor) and is reflected in the observations given in Report 201-1 (remote control signals for facsimile transmission).

9. In the new and developing countries there is a need for relatively low-cost telegraph systems with a small capacity, but nevertheless providing a degree of automatic error correction. As a result of discussions within Study Group III, Reports 348, 349 and 350 were approved, which go some way towards satisfying this need, and furnish a partial reply to Questions 9/IX and 278 (Questions Nos. 4 and 6 of the Plan Sub-Committee for Asia, Geneva, 1963).

RESOLUTION 1-1

IMPROVED EFFICIENCY IN THE USE OF THE RADIO-FREQUENCY SPECTRUM

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that knowledge and technology in the field of radiocommunications are developing rapidly;

(b) that a larger number of simultaneous users of the spectrum must be accommodated in the future;

(c) that the accommodation of these additional users, without serious deterioration of those services in use at present, will require careful consideration of all the many technical factors involved in the simultaneous operation of potentially interfering systems;

(d) that the available information on the wanted-to-interfering signal protection ratios and the operating sensitivities of receiving systems needs further refinement for each of the services, to permit the most efficient planning of the use of the radio-frequency spectrum;

UNANIMOUSLY DECIDES

1. that an International Group of Experts of the C.C.I.R.*, which would be representative of the Study Groups interested in this problem, shall be established, to prepare a report on definitions and procedures for the purpose of enabling the various Study Groups of the C.C.I.R. to provide improved information on:

– the required signal-to-interference protection ratios,

– the minimum field strengths required for various classes of emission,

which would permit the more efficient use of the radio-frequency spectrum by the maximum number of simultaneous users;

2. that the co-ordination of the work of the Group should be undertaken by Study Group III;

3. that, as far as possible, the work of the Group should be conducted by correspondence.

Note. — The Director, C.C.I.R., is invited to bring this Resolution to the attention of the U.R.S.I. for information.

QUESTION 1/III **

FACTORS AFFECTING THE QUALITY OF PERFORMANCE OF COMPLETE SYSTEMS OF THE FIXED SERVICE

The C.C.I.R., (1948 – 1966)

DECIDES that the following question should be studied:

what are the technical factors affecting the quality of performance of complete systems of the fixed service ?

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* The following Administrations: U.S.A. (Chairman), France, Japan, Netherlands, Federal Republic of Germany, United Kingdom and the U.S.S.R., together with the E.B.U. and the I.F.R.B., have already indicated their willingness to form part of this Group.

** Formerly Question 3(III).

STUDY PROGRAMME 1A/III *

FACTORS AFFECTING THE QUALITY OF PERFORMANCE OF COMPLETE SYSTEMS OF THE FIXED SERVICE

Signal-to-noise and signal-to-interference protection ratios for fading signals, bandwidth and adjacent channel spacing

The C.C.I.R., (1959 – 1966)

CONSIDERING

(a) that the conditions for satisfactory performance of a system must take account of the need to receive signals propagated via the ionosphere, which are subject to fading and multipath effects and are accompanied by radio noise and interference;

(b) that studies requiring signal-to-noise and signal-to-interference protection ratios are closely related, and that determination of necessary adjacent channel spacings requires, in addition, consideration of frequency stability and bandwidth of the systems;

(c) that there are a number of different techniques and systems in use in the radiotelegraph and radiotelephone services and, while it is essential to consider the most advanced state of the radio art, it is also necessary to give special study to conventional systems, either affecting integration of landline and radio services, or of concern to the I.F.R.B.:

UNANIMOUSLY DECIDES that the following study should be carried out:

1. Classes of service

The studies concern the following classes of service in regular use in the fixed service but should also give due regard to new techniques and systems, including those under development, for application to the fixed services:

1.1 *Radiotelephony*

1.1.1 Classes of emission: A3, A3A, A3B, A3J, A3H, F3 (above 30 MHz only, with reference to ionospheric-scatter applications);

1.2 *Radiotelegraphy*

1.2.1 Classes of emission: A1, A2, A7, F1, F6;

1.2.2 Modulation rates:

- A1, A2, machine telegraphy 50 and 120 bauds;
- A7, multi-channel VF telegraphy, 50 to 200 bauds per channel;
- F1, 50 to 600 bauds;

1.2.3 Codes:

- 5-unit start-stop;
- synchronous error-detecting and correcting systems using two-condition signalling codes other than the International Alphabet No. 2;
- other systems;

* Formerly Study Programme 3A(III).

1.3 *Facsimile, phototelegraphy, Hellschreiber*

1.3.1 Classes of emission: A4, F4.

2. Minimum conditions required for satisfactory service

2.1 Acceptable criteria and values for:

2.1.1 intelligibility over radiotelephone circuits, for the various grades: just usable, operator-to-operator (order wire); marginally commercial; good commercial;

2.1.2 error-rate for characters and elements over radiotelegraph circuits (efficiency factor for ARQ circuits);

2.1.3 legibility of copy over facsimile (phototelegraphy) and Hellschreiber circuits;

– the maximum duration and percentage of the time during which performance inferior to the standard values can be tolerated;

2.2 Performance of the system as a function of:

– signal-to-noise and signal-to-interference (co-channel) ratios;

– required signal-to-noise and signal-to-interference (co-channel) protection ratios for the acceptable standard values of intelligibility, error-rate (efficiency factor on ARQ circuits), or legibility, for the various services *, considering:

2.2.1 signal fading, taking account not only of the amplitude distribution, but also of the autocorrelation function and the distribution of duration of the fades;

2.2.2 diversity (space, frequency, or time) techniques: noise reducers, coding including the use of error-correcting codes or ARQ, use of more than two signalling conditions, and optimum modulation and detection techniques;

Note 1. – It would be useful to compare the systems using the various telegraph codes, including those of § 1.2.3, in terms of undetected or uncorrected error rate for a given power and signalling speed, in words per minute, and operating under the same conditions. A 5-unit start-stop system may also be used as the reference system by regarding each mutilated character as an error only. It is provisionally suggested that the ratio of error rates should be expressed for two-circuit conditions only; namely, when the system under test is subjected to an average of one undetected or uncorrected error per 1000 characters, and per 10 000 characters.

Note 2. – A special study is needed comparing the different systems used for voice-frequency telegraphy on radio circuits; this is dealt with in Study Programme 18A/III

2.2.3 multipath effects;

2.2.4 interference effects of radio noise of various types, such as atmospheric, impulsive, or Gaussian noise, as described by the wave form and amplitude distribution of the instantaneous values of the noise;

* For radiotelephone services, the signal-to-noise ratio required in the audio band must be specified, and from this the signal-to-noise ratio required in the radio-frequency band is established.

– the resulting interference effects on actual reception, taking account of the method of detection, and of filtering prior to and following detection;

2.2.5 interference effects of co-channel signals representing the various classes of emission, taking account of the spectral and statistical (fading) characteristics of the interfering signal;

2.2.6 monthly mean signal-to-noise ratios and signal-to-interference ratios, required for circuits of various lengths and directions, to meet the acceptable standard values of circuit performance (§ 2.1) during the specified percentage of the time, taking into account;

– the distribution within an hour of the mean values of the short-term (fading) distributions of signals and noise,

– the distribution, within a month or season, for a given hour of the hourly mean values of the signal strengths and atmospheric noise levels (Report 322).

Note. – The monthly mean values of atmospheric noise for various time blocks, and information on the distribution of values within the month, is given in Report 322; with regard to monthly mean values of signal strength, and distribution of hourly values within the month, until such time as C.C.I.R. adopts information on this subject, other standard references may be used such as U.S. National Bureau of Standards Circular No. 462.

This study is intented to lead to revisions or replacement of Recommendations 240, 339-1 and 340.

2.3 Minimum bandwidth required for satisfactory transmission and reception of the intelligence, in a complete system (this is not the question of " bandwidth necessarily occupied ", involving the capability of the transmitting system to avoid radiation outside the band needed for communication, which is included in Study Programme 5A/1).

3. Determination of adjacent channel signal-to-interference protection ratios, and frequency separations between various classes of service, considering

3.1 the use of effective receiving band-pass filters no wider than necessary for satisfactory reception (see § 2.3 above, and Recommendations 237, 330 and 331-1);

3.2 the bandwidth occupied by the interfering transmission;

3.3 the frequency tolerance and stability of the wanted and unwanted signals;

3.4 the studies of § 2.2 above relating to co-channel signal-to-interference protection ratios.

Note. – The result of this study should be presented in the form indicated in the Annex. The results are intended to lead to revision of Recommendation 240.

ANNEX

MINIMUM PROTECTION RATIOS AND FREQUENCY SERARATIONS UNDER STABLE CONDITIONS

Wanted signal		Interfering signal																							
Type of service		A1 100 bauds				F1 2 D = 400 Hz				F4				A3A				A3				Broadcast			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
		dB	kHz			dB	kHz			dB	kHz			dB	kHz			dB	kHz			dB	kHz		
A1	24 bauds (aural)																								
A1	50 (bauds (printer)																								
A1	120 bauds (recorder)																								
F1	50 bauds (printer)																								
F1	120 bauds (recorder)																								
F1	200 bauds (printer ARQ)																								
F4	phototelegraphy																								
A3A	SSB																								
A3	DSB (commercial)																								

Note. – Column 1 gives the limiting values in decibels of signal-to-interference ratio, when the occupied band of the interfering emission either falls entirely within the passband of the receiver, or covers it completely. Columns numbered 2, 3 and 4 indicate the frequency separation necessary between a wanted and an interfering signal when the latter is 0, 6 or 30 dB higher than the wanted signal.

[redacted]

QUESTION 2/III *

ARRANGEMENT OF CHANNELS IN MULTI-CHANNEL TELEGRAPH SYSTEMS FOR LONG-RANGE RADIO CIRCUITS OPERATING ON FREQUENCIES BELOW ABOUT 30 MHz

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

CONSIDERING

(a) that lack of uniformity in the arrangement and designation of the channels in multi-channel telegraph systems, for long-range radio circuits operating at frequencies below about 30 MHz may give rise to certain difficulties when one transmitting station has to work with more than one receiving station;

(b) that many such systems are in use, besides the multi-channel voice-frequency telegraph systems referred to in Question 43;

UNANIMOUSLY DECIDES that the following question should be studied:

what is the best way of arranging and designating the channels in multi-channel telegraph systems for long-range radio circuits, operating at frequencies below about 30 MHz ?

QUESTION 3/III **

DIRECTIVITY OF ANTENNAE AT GREAT DISTANCES

The C.C.I.R., (1948 – 1951 – 1953)

DECIDES to study the following question:

experimental study, by Administrations and various organizations, of the directivity of antennae realized at great distances (taking full advantage of existing transmissions), by any suitable method, for example, by use of mechanically or electrically steered antennae.

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* Formerly Question 74(III).

** Formerly Question 81(III).

STUDY PROGRAMME 3A/III *

IMPROVEMENT OBTAINABLE FROM THE USE OF DIRECTIONAL ANTENNAE

The C.C.I.R., (1953 – 1956 – 1959)

CONSIDERING

(*a*) that Study Programme 1A/III requires knowledge of the improvement in the signal-to-interference ratio that can be obtained by the use of directional antennae on long-distance circuits;

(*b*) that the Annex to Recommendation 162-1 shows median value of discrimination in the form of gains in various arcs, relative to the optimum gain for a half-wave dipole ** at the same height and on the correct azimuth, when the wanted and unwanted emissions are in the range 3000-10 000 km;

(*c*) that it is also important to know the discrimination given by the antenna, when the wanted station or the interfering station, or both, are at much shorter range;

(*d*) that it appears practicable to obtain some reduction of interference by using a null method at the receiver;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the signal power gain in the main lobe provided by practical directional antennae used under actual propagation conditions, relative to a half-wave horizontal dipole ** at the height of the centre of the directional antenna; the median value and cumulative distribution with time of the values of gain during short periods (as, for example, less than an hour), should be observed; observing periods should be suitably distributed and the data studied on a statistical basis, so as to show dependence of results on time of day and season for normal propagation conditions, and the effect of especially critical propagation conditions such as encountered near time of sunrise and sunset, and at times of failure of the operating frequency near the MUF, and at times of ionospheric disturbances;

2. determination of the signal power gain in directions outside the main lobe and/or values of discrimination provided by the antenna between the wanted and interfering signals. The data should include the variations with time, referred to in § 1 above, and should specify directions or the appropriate arcs shown in Fig. 1 of Recommendation 162-1;

3. the effects of the antenna height in increasing the number of hours of useful transmission and in the reduction of interference;

4. the usefulness of a null method of minimizing the interference. The data required to evaluate the usefulness might consist of:

4.1 logs of commercial receiving stations, showing outages due solely to interference and the relative azimuth bearing of interfering stations,

4.2 experimental data on the use of directional antenna systems and antennae with adjustable directions of null, under conditions where interference is experienced.

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* Formerly Study Programme 81A(III).

** The median values of the gain can also be expressed relative to the isotropic antenna.

STUDY PROGRAMME 3B/III *

DIRECTIVITY OF ANTENNAE FOR FIXED SERVICES USING IONOSPHERIC-SCATTER PROPAGATION

The C.C.I.R., (1959)

CONSIDERING

(a) that systems are at present in service using ionospheric-scatter propagation, at frequencies above 30 MHz and that extension of use of this mode of propagation may be expected in the international fixed services;

(b) that it is desirable to establish the preferred characteristics of such systems needed to facilitate their international connection, and that it is particularly important to have similar or matched directivity of the antennae at opposite terminals of the circuit;

(c) that antenna directivity, including the characteristics of radiation pattern, gain, beamwidth and direction of the main lobe or lobes, significantly affects transmission loss, and the possibility of occurrence of multipath propagation and interference to and from other services;

UNANIMOUSLY DECIDES that the following studies should be carried out:

studies of the desirable characteristics of the directivity of transmitting and receiving antennae for international fixed services, using ionospheric-scatter propagation above 30 MHz, including gain, beamwidth and direction of the main lobe or lobes, and tolerances for the radiation pattern outside the main lobe, taking into account:

- dependence on propagation characteristics of the scattering medium, including dependence on scattering angle, size and inhomogeneity of the scattering region;
- effects of meteoric ionization, and the techniques of beam slewing and beam splitting, and how these may depend on season and time of day;
- operating frequency;
- diversity;
- polarization;
- multipath propagation, in relation to the modulation technique used;
- interference to and from other services.

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* Formerly Study Programme 81B(III).

QUESTION 4/III *

RADIO-RELAY SYSTEMS EMPLOYING IONOSPHERIC-SCATTER PROPAGATION

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

CONSIDERING

(a) that experiments have already shown the possibility of utilizing frequencies above 27·5 MHz for transmission by ionospheric-scatter propagation to distances well beyond the horizon;

(b) that systems using this mode of propagation are already in service;

(c) that it is desirable to determine the preferred characteristics of such systems needed to facilitate their international connection;

(d) that the frequency bands, which might be used for such systems, are already intensively used by other services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. how do the propagation characteristics, relevant to the exploitation of systems employing ionospheric-scatter propagation, vary with frequency;

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

3. what are the radio-frequency and baseband characteristics of such systems, which it is essential to specify for the transmission of telephony or telegraphy to enable two systems to be interconnected, and what values should be specified ?

QUESTION 5/III **

COMMUNICATION THEORY

The C.C.I.R., (1951 – 1956 – 1966)

CONSIDERING

(a) that for the transmission of a given quantity of information through a given telecommunication channel with a given power, either in a given time using a minimum bandwidth, or with a given bandwidth in a minimum time, the theoretical formulae suggest the use of pulse-code modulation;

(b) that the theoretical coding method for improving on this involves a long delay;

UNANIMOUSLY DECIDES that the following question should be studied :

what improvement may be expected in the efficiency of existing communication systems as a result of the application of the theory of information ?

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* Formerly Question 132(III).

** Formerly Question 133(III).

STUDY PROGRAMME 5A/III *

COMMUNICATION THEORY

The C.C.I.R., (1951 – 1953 – 1956 – 1963 – 1966)

CONSIDERING

(a) that, in view of the increasing congestion of the radio-frequency spectrum and telecommunication circuits, it would be advantageous to discover technical methods of decreasing the bandwidth, the transmission time or the transmitted power necessary for the transmission of a given quantity of information;

(b) that present studies seek mainly to perfect established systems, whereas recent theories seem to show that these systems occupy several times the bandwidths strictly necessary for the transmission of the required information at the required speed;

(c) that, even with existing systems, it is not possible to reduce the bandwidth to that strictly necessary because of unpredictable noise, natural and man-made interference, and complex propagation conditions; a margin of bandwidth is necessary to decrease distortion and the frequency of errors due to these phenomena;

(d) that it is not certain that existing codes, some at least of which were not designed in the light of phenomena peculiar to radio propagation, are making the best use of the occupied bandwidth;

(e) that, to assess the effectiveness of any error-detecting or error-correcting codes over radio circuits, it is essential that realistic error statistics be known for these radio circuits;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the review of the various codes in use and the study of new codes, leading to an economy of bandwidth or transmission time for a given quantity of information and a given quality of transmission, taking into account the phenomena peculiar to radio propagation and the relative merits of the various existing systems of modulation from the point of view of the bandwidth occupied in relation to the amount of information transmitted in a given time for a given power;

2. the determination of the transmission capacity obtainable in practice with regard to systems with:

2.1 full duplex operation;

2.2 half-duplex operation (common frequency or otherwise);

2.3 simplex operation;

3. the experimental determination of error statistics for operating radio circuits. The result of such experiments should provide a table, showing the frequency of occurrence of m errors in a sequence of n digits ($m = 0, 1, 2, 3 \ldots$). Where this is possible, it may be useful to give information on the occurrence of the different types of errors. The suggested range of values for n is between 7 and about 100;

4. the study, in conjunction with the U.R.S.I., of the methods of communication theory that are best suited for practical application.

Note. – The information asked for under §§ 2 and 3 should, where possible, state the conditions of the channel: signal-to-noise ratio, fading characteristics, special noise or channel disturbances, interference from other stations, etc.

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* Formerly Study Programme 133A(III).

QUESTION 6/III *

USE OF INTERMITTENT COMMUNICATION IN RADIOTELEGRAPHY

The C.C.I.R., (1959)

CONSIDERING

(a) that the method of intermittent communication is coming into use, particularly for circuits using meteoric ionization;

(b) that intermittent communication often enables the mean telegraph speed to be increased considerably, for a given quality of service, when the signals and interference at the receiver are random in character;

(c) that insufficient data are so far available concerning the fields in which it would be opportune to apply the principle of intermittent communication;

UNANIMOUSLY DECIDES that the following question should be studied:

1. under what conditions is the use of intermittent communication advantageous in radiotelegraphy;

2. what advantages, as regards telegraph speed, can be expected from the use of intermittent communication under various conditions, as compared with the usual uninterrupted method;

3. what is the most rational course to be followed in the construction of equipment for the use of intermittent communication under various conditions ?

QUESTION 7/III **

INFLUENCE OF FREQUENCY DEVIATIONS ASSOCIATED WITH PASSAGE THROUGH THE IONOSPHERE ON HF RADIOCOMMUNICATIONS

The C.C.I.R., (1956 – 1959 – 1966)

CONSIDERING

(a) that Recommendation 246–1 recommends that, for frequency-shift systems working on two conditions only and operating between 3 and 30 MHz ,the values of frequency-shift should be 200, 400, and for modulation rates above 250 bauds, 500 Hz;

(b) that preferred values for the channel spacing and frequency-shifts of multi-channel voice-frequency telegraph systems for use on HF radio circuits are given in Recommendation 436;

(c) that study of frequency deviations, associated with passage through the ionosphere, has shown that the resultant frequency variations may reach values of a few cycles per second, while instantaneous deviations may reach much higher values (see Report 111 and the Annex to Recommendation 349–1);

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* Formerly Question 180(III).

** This Question replaces Questions 181 and 182.

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the statistical distributions of frequency deviation associated with passage through the ionosphere in magnitude, duration and frequency of occurrence;
2. what minimum value of frequency-shift is required for frequency-shift systems operating by HF ionospheric propagation, to take into account:
   - the frequency stability of the equipment (see Recommendation 349-1);
   - the frequency deviations referred to in § 1 ?

QUESTION 8/III *

FREQUENCY-SHIFT KEYING

The C.C.I.R., (1948 – 1959)

CONSIDERING

(a) that frequency-shift keying is employed in radiotelegraphy for the fixed services and it has also been extended to the mobile services;

(b) that it is desirable to standardize the main operating characteristics of systems employing frequency-shift keying;

(c) that various technical factors influence the choice of operating characteristics in such systems, in particular:

c.a the overlap of marking and spacing signals due to multipath propagation (in this respect a small deviation is preferable);

c.b the possible advantage of frequency diversity for reception (an advantage which increases with deviation);

c.c economy of bandwidth and the consequent necessity for controlling the shape of the transmitted signals;

c.d instability of frequency, which is one reason for the relatively large deviation employed in many existing equipments;

c.e the choice of receiving systems, whether with separate filters or with frequency discriminator;

UNANIMOUSLY DECIDES that the following question should be studied:

1. fixation of one or more standard values of deviation for fixed and mobile services in the various frequency bands, having regard to the various factors, in particular:
   - the frequency spectrum resulting from the keying operation;
   - the degree of frequency diversity desired;
   - economy of bandwidth;
   - instability of frequencies;
2. compilation of a standard terminology regarding the characteristics of systems employing frequency-shift keying.

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* Formerly Question 183(III).

STUDY PROGRAMME 8A/III *

FOUR-FREQUENCY DIPLEX SYSTEMS

The C.C.I.R., (1956 - 1959)

CONSIDERING

(a) that there are in use, in the fixed radiotelegraph services, operating between 2 MHz and 27 MHz, four-frequency diplex (or twinplex) systems, in which each of four frequencies is used to transmit one of the four possible combinations of mark and space signals corresponding to two telegraph channels; it being understood that either or both of the two telegraph channels may be sub-channelled by time-division methods and that the use of such systems may be extended;

(b) that it is desirable to standardize the main characteristics of four-frequency diplex systems;

(c) that it may sometimes be necessary to employ the same radio transmitter to work with more than one receiving station;

(d) that various technical factors influence the choice of operating characteristics in such systems, in particular:

- economy of bandwidth and the consequent need to control the shape of the transmitted signals;
- a relatively wide spacing between adjacent frequencies may be necessary for high telegraph speeds;
- the signal distortion due to propagation conditions;
- the instability of the characteristics of certain receiver and transmitter elements, such as oscillators, filters or discriminators;

UNANIMOUSLY DECIDES that the following study should be carried out:

the determination of the relation between the minimum frequency spacing and the telegraph speed over the range of telegraph speeds in practical use. This should be determined for both synchronous and non-synchronous operations.

QUESTION 9/III **

USE OF COMMON-FREQUENCY SYSTEMS ON RADIOTELEPHONE CIRCUITS

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

CONSIDERING

(a) that relief of the present congestion of the HF (decametric) band is a matter of urgency;

(b) that, in certain cases, the use of the same carrier frequency in both directions of a radiotelephone circuit (in combination with techniques that prevent simultaneous transmission in both directions) may result in economies in spectrum utilization on a radiotelephone circuit;

* Formerly Study Programme 183B(III).

** This Question replaces Question 233.

UNANIMOUSLY DECIDES that the following question should be studied:

1. in which cases does the use of the same frequency in both directions of transmission result in more effective sharing of frequencies;

2. in such cases:

2.1 what are the characteristics to be specified for radiotelephone systems using the principles of common-frequency operation;

2.2 what should be the minimum difference in level at the input to the receiver, between the received signal from the distant station and signals from the nearby transmitting station, to avoid interference between the wanted signal and that from the nearby transmitter operating on the same frequency;

2.3 to what extent will the use of transmitting and receiving antennae with different transmission characteristics reduce the possibilities of application of this technique;

2.4 to what extent will the possibilities of application of this technique be reduced by the presence of different noise levels at the receiving locations;

2.5 what other factors should be taken into account when planning such systems, for example:

- non-linearities in the transmitting and receiving equipment,
- carrier-filter bandwidth,
- frequency stability of the equipment ?

QUESTION 10/III *

USE OF DIRECTIONAL ANTENNAE IN THE BANDS 4 TO 27·5 MHz

Limitation of radiation outside the direction necessary for the service

THE INTERNATIONAL FREQUENCY REGISTRATION BOARD,

IN VIEW OF the request by the Panel of Experts in Recommendation No. 38 of its Final Report, Geneva, 1963, and AFTER CONSIDERING:

(a) that there is serious congestion in the frequency bands between 4 and 27·5 MHz;

(b) that there is a need to adopt methods and regulations for the solution of the frequency problems with which Administrations are confronted in the use of these bands;

(c) that occupation of the radio-frequency spectrum is represented, not only in time and bandwidth, but also in the spatial distribution of the radiated power;

(d) that this latter distribution can be effectively controlled by the use of directional antennae:

(e) that the intent of Articles 12 and 14 of the Radio Regulations, Geneva, 1959, would seem to justify further explicit requirements for the use of directionnal antennae in the bands between 4 and 27·5 MHz, as well as for quantitative limitation of the intensity of radiation in directions other than that required for the service;

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* Formerly Question 280(III).

AND IN VIEW OF No. 180 of the International Telecommunication Convention, Geneva, 1959;

DECIDES to submit the following urgent question to the C.C.I.R.:

what are reasonable standards for the directivity of antennae in the various types of radio services, and for various distances, in the bands between 4 and 27·5 MHz, including the width of the main beam and the allowable intensity of radiation (effective radiated power) in directions of azimuth outside the main beam (such standards should reflect due regard for practical considerations of construction and cost) ?

QUESTION 11/III *

AUTOMATIC CONTROL OF THE OUTPUT POWER OF THE TRANSMITTERS

THE INTERNATIONAL FREQUENCY REGISTRATION BOARD,

IN VIEW OF the request of the Panel of Experts in Recommendation No. 38 of its Final Report, Geneva, 1963, and AFTER CONSIDERING:

(a) that No. 694 of the Radio Regulations, Geneva, 1959, requires that all stations shall radiate only as much power as is necessary to ensure a satisfactory service;

(b) that nevertheless, for a considerable part of the time, stations using frequencies in the bands between 4 and 27·5 MHz, radiate powers considerably in excess of those necessary to ensure a satisfactory service;

(c) that manually operated methods of adjusting the power of transmitters are not fully adequate to meet No. 694 of the Radio Regulations;

(d) that the use of automatic control of the output power of transmitters would assist in reducing the congestion in the HF spectrum;

AND IN VIEW OF No. 180 of the International Telecommunication Convention, Geneva, 1959;

DECIDES to submit the following urgent question to the C.C.I.R.,

what are the most suitable methods for automatically controlling the output power of radio transmitters operated in the HF bands to ensure, as far as is practicable, that the radiated power is no greater than is necessary to ensure a satisfactory service ?

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* Formerly Question 281(III).

QUESTION 12/III

DISTORTION CHARACTERISTICS REQUIRED FOR SINGLE-SIDEBAND AND INDEPENDENT-SIDEBAND SYSTEMS USED FOR HIGH-SPEED DATA TRANSMISSION OVER HF RADIO CIRCUITS

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

CONSIDERING

(a) that an increasing demand is noted for high-speed data transmission over HF radio circuits and further increase in such demand may be expected;

(b) that recent developments are leading to systems having greatly improved bandwidth efficiency, i.e. a larger capacity in bits per second per unit bandwidth;

(c) that it is desirable that the effects of the random variations and disturbances in the propagation medium be the ultimate factors governing the performance obtainable with such systems;

(d) that the characteristics of a " 3 kHz channel " have largely been evolved from the use of such channel for telephony;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the permissible limits of amplitude, phase and delay distortion on HF radio circuits intended for high-speed data transmission (e.g. 2400 bits/s and above), excluding *a priori* effects due to the radio propagation medium;

2. are these limits likely to be exceeded in HF systems of the fixed service currently available;

3. should new channel arrangements for data-transmission be recommended, differing from the present standards for the 3 kHz channel, as defined in Recommendation 348-1 for radiotelephony;

4. in evaluating high-speed data transmission systems, what statistical parameters should be used to describe the radio propagation medium and what values should be considered ?

QUESTION 13/III

IMPROVEMENTS IN THE PERFORMANCE OF HF RADIOTELEPHONE CIRCUITS

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

CONSIDERING

(a) that there is a need to improve the quality of transmission of HF radiotelephone circuits;

(b) that the use of diversity techniques may offer the prospect of such an improvement;

(c) that other methods of improvement, e.g. the adaptation of compandor principles might become available;

(d) that these techniques might be used either separately or in combination;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the various methods whereby diversity can be obtained on HF radiotelephone circuits;

2. what other methods are available for obtaining such improvements;

3. what improvement of performance is to be expected with these methods ?

QUESTION 14/III

AUTOMATICALLY CONTROLLED RADIO SYSTEMS IN THE HF FIXED SERVICE

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

CONSIDERING

(a) that successful development of fully automatic transmitting and receiving terminals may offer important improvements in efficiency, reliability and economy of operation in the fixed service;

(b) that certain features of automatic control may require cooperation and exchange of information between transmitters and receivers, as for example, for change of frequency and power;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what features of automatically controlled radio systems in the HF fixed service require cooperation between Administrations;

2. what are the preferred methods of exchanging and utilizing such information ?

QUESTION 15/III

THE OPERATIONAL USE OF EFFICIENCY FACTOR

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

CONSIDERING

(a) that the efficiency factor discussed in Study Programme 18A/III is very useful for defining and determining the quality of a communication channel using error correction by automatic repetition;

(b) that the efficiency factor could be of use in the operation of radio telex circuits with fully automatic switching;

(c) that, however, data justifying the fixing of definite values of the efficiency factor for purposes of switching a radio channel into or out of a telegraph network have not yet been accumulated in sufficient quantity;

UNANIMOUSLY DECIDES that the following question should be studied:

1. to establish when:

- a radiotelegraph channel should be switched into the network;
- an operational radiotelegraph channel should be switched out of the network;

1.1 can a single value for the efficiency factor (e.g. 80%) be recommended to C.C.I.T.T. for both cases;

1.2 if two values of the efficiency factor are necessary, what should be the preferred values;

2. are the values for the time intervals given below acceptable or are other values to be preferred;

2.1 20 s for the efficiency factor to stay above 80% before a call can be set up;

2.2 60 s for the efficiency factor to stay below 80% before an existing call should be interrupted;

3. what techniques should be used to evaluate whether the efficiency factor during the 20 s interval can be considered to have been above 80%, or during a 60 s interval can be considered to have fallen below 80%?

QUESTION 16/III

TRANSMISSION CHARACTERISTICS OF HF RADIOTELEPHONE CIRCUITS

(1965)

The INTERNATIONAL TELEGRAPH and TELEPHONE CONSULTATIVE COMMITTEE,

INVITES THE C.C.I.R. to study the following question:

would it be possible to improve the transmission characteristics of HF radiotelephone circuits to provide an acceptable service for automatic telephone traffic using C.C.I.T.T. signalling systems Nos. 4 and/or 5 ?

Note 1. – For example, a loss probability of 1/1000 due to transmission difficulties on the telephone channel could be admitted.

Note 2. – Specifications for the two-frequency signalling system (C.C.I.T.T. System No. 4) appear in Vol. VI of the Red Book, pages 126-135 and for the C.C.I.T.T. intercontinental signalling system No. 5 in Doc. AP/III-No. 26, pages 22-46.

Note 3. – This Question follows on the conclusions reached by C.C.I.T.T. Study Group XIII in regard to the use of HF radiotelephone circuits for the routing plan for automatic telephone traffic:

- the use of HF radio circuits in a *semi-automatic* intercontinental group which also includes cable circuits is not acceptable unless the radio circuits offer a grade of service that is

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* Formerly Question 317(III).

almost always comparable to that of the cable circuits, both from the transmission and the signalling aspects;

- for the time being, the use of HF radio circuits in *automatic* operation cannot be considered.

STUDY PROGRAMME 17A/III *

VOICE-FREQUENCY (CARRIER) TELEGRAPHY ON RADIO CIRCUITS

The C.C.I.R., (1951 – 1953 – 1959 – 1966)

CONSIDERING

(a) that different methods are now in use for voice-frequency telegraphy on radio circuits operating below 30 MHz subject to fading, noise and interference;

- either using equipment normally designed for landline working and suitably adapted for radio;
- or using equipment especially designed for radio working;

(b) that studies carried out so far show that it is impossible to compare transmission systems in which the two significant conditions of modulation are obtained either by the frequency exchange method or by the method of frequency-shift of a single voice-frequency oscillator, without taking into account all the properties of the equipment and of the propagation medium;

(c) that experience in reception of voice-frequency telegraphy over radio circuits has shown that frequency-modulated voice-frequency telegraph equipment for use on radio circuits may differ substantially from voice-frequency landline equipment; this equipment may, therefore, have to be designed and constructed with their special purpose in mind;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. comparisons of the different systems used to transmit and receive voice-frequency telegraphy on radio circuits subject to the effects of fading, multipath propagation, noise and interference, with a view to standardizing their characteristics, taking into account the following techniques and factors:

- frequency-shift keying of one voice-frequency oscillator;
- transmitting the two significant conditions of modulation by the two-tone method;
- other modulation systems, e.g. phase-modulation systems, or systems of modulation employing more than two significant conditions of modulation;
- reception by discriminator or separate filters;

2. influence of the modulation index (frequency shift (Hz)/modulation rate (bauds)) and the channel spacing on the error-rate.

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* This Study Programme, which replaces Study Programme 43A, does not derive from any Question under study.

STUDY PROGRAMME 18A/III *

EFFICIENCY FACTOR

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

CONSIDERING

(a) that the efficiency factor, as defined in the " List of definitions of essential telecommunication terms " (Part 1, 1961, No. 33.23; see also Recommendation 345), is very useful for defining and determining the quality of a communication channel using error-correction by automatic repetition;

(b) that measurements of the efficiency factor could be of use in the operation of radiotelegraph telex circuits with fully automatic switching;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the way in which measurements of the efficiency factor may be used to analyse and predict the performance of systems with error-correction by automatic repetition;

2. the way in which measurements of the efficiency factor may be used on radio circuits which are part of networks with fully automatic switching;

3. development of standards for appropriate equipment for assessing the efficiency factor, taking into account the following:

3.1 measurement of the efficiency factor with time intervals appropriate to:

3.1.1 the general case of analysing the performance of systems with error-correction by automatic repetition;

3.1.2 the particular case of analysing radio circuits which are part of networks with fully automatic switching;

3.2 establishment of suitable criteria indicating the operational quality of the system or the radio circuit, and establishment of two specific conditions corresponding to the requirements for setting up a call and the necessity of interrupting an existing call.

Note 1. – Measurements should preferably be carried out in successive periods based on time intervals of 10 min for long period evaluation and of 20 s for detailed analyses, converted for reasons of convenience into the equivalent number of character cycles and the following information should be recorded:

- the number of telegraph signals repeated;
- the number of telegraph signals incorrectly translated by the telegraph apparatus;
- the total number of telegraph signals received by the telegraph apparatus;
- the type of telegraph apparatus used;
- the type of error-correction equipment in use, with an indication of the number of telegraph signals in the repetition cycle and the operational conditions during the non-print cycle;
- modulation rate used in the telegraph channel and in the radio channel;
- date and time of observation.

Note 2. – Measurements should be made throughout the day, using normal operating frequencies. If possible, an attempt should be made to determine whether a correlation exists between the results of the efficiency factor measurements and the performance of the radio circuit as based on observations at the radio receiving stations.

* This Study Programme, which replaces Study Programme 186, does not derive from any Question under study.

Note 3. – When the radio circuit is part of a network with fully automatic switching, the C.C.I.T.T. is considering:

- fixing one limit (80%) for the efficiency factor on operational circuits with fully automatic switching;
- a time interval of 20 s during which this limit must be exceeded before a call can be set up;
- a time interval of 60 s during which the efficiency factor has remained below this limit before an existing call can be interrupted.

STUDY PROGRAMME 19A/III *

IDENTIFICATION OF THE CARRIER FREQUENCY RELATIVE TO THE ASSIGNED FREQUENCY OF AN EMISSION

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

CONSIDERING

(a) that in certain classes of emission, notably single-sideband and suppressed or reduced carrier types, the carrier frequency is not in the centre of the assigned frequency band and does not therefore coincide with the assigned frequency;

(b) that the exchange of operating information, between the terminals of a radio circuit, is facilitated if there is a simple method of identifying the carrier frequency of such an emission;

(c) that the assigned frequency forms a convenient reference, relative to which the carrier frequency may be located;

UNANIMOUSLY DECIDES that the following studies should be carried out:

investigation of the application of the method of carrier frequency identification (see Report 202) and assessment of the advantages to be gained by the use of such a method.

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* This Study Programme, formerly Study Programme 187 (III), does not derive from any Question under study.

STUDY PROGRAMME 20A/III *

OPERATIONAL IONOSPHERIC SOUNDING AT OBLIQUE INCIDENCE

The C.C.I.R., (1965 – 1966)

CONSIDERING

(a) that sounding of the ionosphere at oblique incidence has proved to be an effective method for observing the behaviour of HF radio waves propagated via the ionosphere;

(b) that the information obtained from oblique incidence sounding may be used to improve the performance of some long-distance radio circuits;

(c) that such sounding carried out as an operational procedure may give rise to harmful interference, particularly if used indiscriminately;

(d) that with increasing use difficulty may be experienced in identifying emissions from particular sounders;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the methods by which the information obtained from sounding of the ionosphere at oblique incidence (see Study Programme 12A/VI) could be used to improve the operational efficiency of long-distance radio circuits;

2. the limitations, if any, in such characteristics as emitted power and number of simultaneous emissions that are desirable to avoid harmful interference;

3. the measures necessary to enable such emissions to be identified;

4. the preferred characteristics of the equipment used for operational ionospheric sounding that will promote effective co-operation between the greatest number of users.

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* This Study Programme, which replaces Study Programme 208, does not derive from any Question under study.

LIST OF DOCUMENTS CONCERNING STUDY GROUP III (PERIOD 1963-1966)

Doc.	Origin	Title	Reference
III/1	United Kingdom	Operational ionosphere sounding at oblique incidence	S.P. 197(VI)
III/2 and Corr.1	C.C.I.R. Secretariat	Remote control signals for fascimile transmissions. Texts of the IIIrd Plenary Assembly of the C.C.I.T.T.	Rep. 201
III/3 and Corr. 1	C.C.I.R. Secretariat	Standardization of phototelegraph systems for use on combined radio and metallic circuits. Texts of the IIIrd Plenary Assembly of the C.C.I.T.T.	Rec. 344
III/4 and Corr.1	C.C.I.R. Secretariat	Facsimile transmission of documentary matter over combined radio and metallic circuits. Texts of the IIIrd Plenary Assembly of the C.C.I.T.T.	Q. 232
III/5 and Corr.1	C.C.I.R. Secretariat	Voice-frequency(carrier) telegraphy on radio circuits. Texts of the IIIrd Plenary Assembly of the C.C.I.T.T.	S.P. 43A
III/6 and Corr.1	Netherlands	Draft Recommendation – Telegraph system for isolated areas and for the mobile services	S.P. 3A(III)
III/7	United States of America	Diversity techniques for HF radio-telegraphy	Q. 225(II), 3(III) S.P. 3A(III)
III/8	United Kingdom	The relative performance of telegraph systems using frequency-division multiplex on HF radio circuits	S.P. 43A
III/9	United States of America	Draft Report – Use of common-frequency systems on international radiotelephone circuits	Q. 233
III/10	United States of America	Draft of new Question – Use of diversity on international HF radiotelephone circuits	
III/11	United States of America	Use of diversity on international HF radiotelephone circuits	
III/12	United States of America	Bandwidth and signal-to-noise ratios in complete systems	Rep. 195, Q.3 S.P. 3A(III)
III/13	United States of America	Some aspects of the application of communication theory	Q. 133 Rep. 196
III/14	United States of America	Frequency stability required for single-sideband, independent-sideband and telegraph systems to make the use of automatic frequency control superfluous	Q. 182 Rec. 349
III/15	United States of America	Draft New Question – HF radio terminal equipment characteristics for high speed data transmission	
III/16	United States of America	Revisions for Report 109 – Radio systems employing ionospheric scatter propagation	Rep. 109 Q. 132
III/17	United States of America	Revision of Recommendation 344 – Transmission of half-tone pictures over radio circuits	Rec. 344 Q. 95

Doc.	Origin	Title	Reference
III/18	United States of America	Draft Recommendation – Measurement of isochronous telegraphic distortion	Rec. 345
III/19	United Kingdom	Radiotelegraph circuits used in automatic switched networks	S.P. 3B(III)
III/20	Federal Republic of Germany	Voice-frequency (carrier) telegraphy on radio circuits	Q. 43 S.P. 43A
III/21	Federal Republic of Germany	Factors affecting the quality of performance of complete systems of the fixed services (automatic error correction) – Proposed modifications to Recommendation 342	Rec. 342 S.P. 3A(III)
III/22 and Corr.1	Federal Republic of Germany	Factors affecting the quality of performance of complete systems of the fixed services – Draft Recommendation concerning a single-channel ARQ system	S.P. 3A(III)
III/23	Federal Republic of Germany	Efficiency factor	S.P. 186
III/24	Federal Republic of Germany	Efficiency factor	S.P. 186
III/25	United Kingdom	Improvement obtainable from the use of directional antennae – Measurements of vertical angles of wave-arrival	S.P. 81A
III/26	Netherlands	Proposed modification to Recommendation 349	Rec. 349
III/27	Study Group III	Interim Report by the Chairman	
III/28	Japan	Modulation index for voice-frequency telegraphy on radio circuits	S.P. 43A
III/29	Japan	Efficiency factor	S.P. 186
III/30 and Corr.1	Japan	Use of common-frequency systems on international radiotelephone circuits	Q. 233
III/31 and Corr.1	Japan	Relation between the density of a picture and the degree of modulation	Q. 95
III/32	W.M.O.	Standards for the facsimile transmission of meteorological charts	Rep. 201 Q. 232
III/33	International Working Party III/1	Optimum use of the radio-frequency spectrum	Res. 1
III/34	International Working Party III/1	Operating sensitivity of a radio receiving system	Res. 1
III/35	U.R.S.I.	Communication theory	Q. 133 Rep. 196
III/36	Canada	Operational oblique incidence ionosphere sounding	S.P. 197(VI)
III/37	U.S.S.R.	Reliability calculation of radiocommunication on short waves	Rec. 340
III/38	U.S.S.R.	Supplement to Recommendation 340	Rec. 340
III/39	U.S.S.R.	New Draft Question – Technical characteristics of automatized radiolink equipment	
III/40	Study Group III	Summary record of the first meeting	
III/41	United States of America	Draft Recommendation – Use of directional antennae in the bands 4 to 27·5 Mc/s	Q. 280
III/42	Working Group III-D	Draft Question – Distortion characteristics required for single-sideband and independent-sideband systems used for data transmission over HF radio circuits	

Doc.	Origin	Title	Reference
III/43	Working Group III-C	Draft Report – Operating threshold of a radio receiving system	
III/44 and Rev. 1	Working Group III-B	Proposed modifications to Recommendation 349	
III/45 and Rev. 1	Working Group III-A	Proposed modification to Recommendation 344	
III/46	Working Group III-A	Draft Report – Remote control signals for facsimile transmission	Q. 232
III/47 and Rev. 1	Working Group III-D	Proposed modifications	Rec. 166 Q. 133 S.P. 3A, 133A
III/48	Working Group III-D	Draft Question – Factors affecting the quality of performance of complete systems of the fixed services	
III/49	Working Group III-A	Proposals concerning those texts of the Xth Plenary Assembly which are of interest to Working Party III-A-3	
III/50	C.C.I.R. Secretariat	List of documents issued (III/1 to III/50)	
III/51 and Rev. 1	Working Group III-B	Draft Recommendation – Arrangement of voice-frequency telegraph channels on radio circuits	
III/52 and Corr. 1	Working Group III-B	Draft Report – The relative performance of telegraph systems using frequency-division multiplex on HF radio circuits	S.P. 43A
III/53	Working Group III-B	Draft modification to Annex I of Recommendation 342	
III/54, Rev. 1 and Corr. 1	Working Group III-A	Report – Use of common-frequency systems on international radiotelephone circuits	Q. 233
III/55	Working Group III-D	Draft Report – Some aspects of the application of communication theory	Q. 133
III/56	Working Group III-A	Draft statement for inclusion in the report by the Chairman, Study Group III	
III/57	Working Group III-A	Draft addition to Report 107 – Directivity of antennae at great distances	Q. 81
III/58	Working Group III-A	Draft Question – Improvements in the performance of the HF radiotelephone circuits	
III/59	Working Group III-A	Draft Study Programme – Operational ionospheric sounding at oblique incidence	
III/60	Working Group III-D	Proposed amendments to Draft Report (Doc. II/36)	
III/61	Study Group III	Summary record of the second meeting	
III/62	Working Group III-A	Draft Question – Automatic radio-links in the HF fixed service	
III/63	Working Group III-B	Draft Question – Influence on high-frequency communications of frequency deviations associated with passage through the ionosphere	
III/64	Working Group III-B	Draft Study Programme – Efficiency factor	

Doc.	Origin	Title	Reference
III/65	Working Group III-B	Proposed modifications to Recommendation 246 – Frequency-shift keying	
III/66	Working Group III-A	Draft note for inclusion in the report by the Chairman, Study Group III	
III/67	Working Group III-A	Draft note for inclusion in the report by the Chairman, Study Group III	
III/68	Working Group III-A	Draft – Statement for inclusion in the report by the Chairman, Study Group III	
III/69	Working Group III-A	Revision of Question 233 (III) – Use of common-frequency systems on radiotelephone circuits	
III/70	Working Group III-B	Draft Report – Voice-frequency telegraphy on radio circuits	S.P. 43A
III/71, Corr. 1 and Rev.1	Working Group III-B	Draft Report – Use of radio circuits in association with 5-unit start-stop apparatus	S.P. 43A
III/72	Working Group III-A	Draft Report – Operational ionospheric sounding at oblique incidence	
III/73	Working Group III-A	Proposed modifications to Report 109 – Radio systems employing ionospheric scatter propagation	
III/74	Working Group III-A	Proposals concerning those texts of the Xth Plenary Assembly which are of interest to Sub-Working Party III-A-3	
III/75	Working Group III-A	Text to be included in the report of the Chairman, Study Group III	
III/76	Working Group III-A	Proposed modifications to Recommendation 348	
III/77	Working Group III-A	Proposed modifications to Recommendation 335	
III/78	Working Group III-B	Proposed amendments to C.C.I.R. texts	
III/79	Working Group III-B	Draft Report – Efficiency factor	
III/80	Working Group III-B	Draft modification to Annex I of Recommendation 342	
III/81	Working Group III-A	Draft Report – Use of pre-emphasis and de-emphasis for phototelegraph transmission on HF radio circuits	S.P. 3A(III)
III/82	Working Group III-B	Draft Report – Single channel Simplex telegraph system for isolated areas and for the mobile services	S.P. 3A(III)
III/83, Corr. 1 and Rev. 1	Working Group III-B	Draft Report – Telegraph distortion error-rate	
III/84	C.C.I.R. Secretariat	Status of texts at the end of the Interim Meeting, Geneva, 1965	
III/85	Study Group III	Summary record of the third meeting	
III/86	Working Group III-C	Draft Report – Optimum use of the radio-frequency spectrum	
III/87	Working Group III-B	Draft note for inclusion in the report by the Chairman, Study Group III	

Doc.	Origin	Title	Reference
III/88	Study Group III	Summary record of the fourth meeting	
III/89	Study Group III	Summary record of the fifth and last meeting	
III/90	C.C.I.R. Secretariat	List of participants	
III/91	C.C.I.R. Secretariat	List of documents (III/51 to III/91)	
III/92	United Kingdom	Automatic error-correcting system for telegraph signals transmitted over radio links – Comments on Doc. III/80	Rec. 342. Ann. I
III/93	United Kingdom	Automatic error-correcting system for telegraph signals transmitted over radio links – Comments on Doc. III/53	Rec. 342
III/94	United Kingdom	Single-channel radiotelegraph system with automatic error-correction – Comments on Doc. III/22	Draft Rec.
III/95	United Kingdom	An improved transmission system for HF radiotelephone circuits	Draft Q.
III/96	United Kingdom	Voice-frequency telegraphy on radio circuits – Use of 120 c/s-spaced systems for 100 baud synchronous operation	S.P. 43A
III/97	United Kingdom	Use of directional antennae in the bands 4 to 27·5 Mc/s	Q. 280
III/98	United Kingdom	Draft Rec. – Use of directiona antennae in the bands 4 to 27·5 Mc/s	Rec. 162
III/99	United States of America	Improvements in the performance of HF radiotelephone circuits	Q. 317 Draft Q.
III/100	C.C.I.R. Secretariat	List of documents issued (III/92 to III/100)	
III/101	United States of America	Proposed modifications to Recommendation 339 – Bandwidths and signal-to-noise ratios in complete systems	Rec. 339
III/102	Italy	Tables for the computation of distorted AM envelopes	Draft Q. Draft S.P.
III/103	Netherlands	Automatic error-correcting system for telegraph signals transmitted over radio links	Draft Rec.
III/104	Netherlands	Factors affecting the quality of performance of complete systems of the fixed service	Draft S.P.
III/105 (II/62)	U.S.S.R.	Sensitivity and noise factor – A method of measuring static characteristics of radiotelegraph receivers	Q. 228 Draft S.P.
III/106 and Rev.1	Companhia Portuguesa Radio Marconi	Efficiency factor	Draft S.P.
III/107 (XIII/105)	Netherlands	Single-channel telegraph system for message broadcasting with error-correcting facility	Draft S.P. Q. 320(XIII)

Doc.	Origin	Title	Reference
III/108	C.C.I.R. Secretariat	Voice-frequency telegraphy on HF radio circuits	Q. 43
III/109, Add.1 and 2	Chairman, S.G. III	Report by the Chairman – Fixed service systems	
III/130 (XIII/113)	F.R. of Germany	Factors affecting the quality of performance of complete systems – Full-duplex single channel ARQ system	S.P. 3A (III)
III/111	C.C.I.R. Secretariat	Submission of Doc. COM XIV – No. 18 of the C.C.I.T.T. Transmission channels for facsimile telegraphy	Q. 95 Q. 232 Rec. 343, 344
III/112 (II/75)	U.S.S.R.	Design of the reception channel of an ionospheric-scatter link	Rec. 338
III/113	C.C.I.R. Secretariat	Submission of Doc. XIII/82 – The introduction of direct printing telegraph equipment in the maritime mobile service – A report on trials of an automatic single-path error-correcting system	Draft S.P. Q. 320 (XIII)
III/114	United States of America	Performance of high-speed data transmission systems on HF radio circuits	Q. 3(III)
III/115	United States of America	Comments on C.C.I.R. documents relating to error control	Draft Q. Q. 320(XIII)
III/116	United States of America	Study of forward-acting, burst error-correcting coding systems for telegraphy and data transmission	Draft Q. Q. 133(XIII), 320(XIII)
III/117	United States of America	Draft of an addendum to Report C.q(III), some aspects of the application of communication theory	Draft Q.
III/118	France	Arrangement of voice-frequency telegraph channels on radio circuits	Draft Rec.
III/119	France	Voice-frequency multi-channel telegraphy on radio circuits – Influence of channel spacing	Q. 43
III/120	Study Group III	Summary record of the first meeting	
III/121	Study Group III	Proposed modification to Recommendation 339 – Bandwidths and signal-to-noise ratios in complete systems	
III/122	Study Group III	Draft Recommendation – Use of directional antennae in the bands 4 to 27·5 Mc/s	
III/123	Working Group III-A	Draft Report – Use of diversity on international HF radiotelephone circuits	Draft Q.
III/124	Working Group III-A	Draft Report – An improved transmission system for HF radiotelephone circuits	Draft Q.
III/125 and Add.1	Working Group III-A	Report by the Chairman	
III/126	Study Group III	Proposed modification to Draft Report C.u(III)	
III/127	Study Group III	Draft Study Programme – Voice-frequency (carrier) telegraphy on radio circuits	
III/128	Study Group III	Proposed modifications to Draft Study Programme C.al(III) – Efficiency factor	

Doc.	Origin	Title	Reference
III/129	Study Group III	Draft additions to Report 197	
III/130 (X/169)	Ad Hoc Committee X/III	Consideration of Doc. III/43 (Rev.1), Draft Report C.t(III), Doc. III/86 (Rev.1), Draft Report C.aa(III)	
III/131	Study Group III	Summary record of the second meeting	
III/132 and Add.1	Working Group III-B	Report by the Chairman	
III/133	Working Group III-C	Draft Report – Efficiency factor	
III/134	Working Groups III-B and III-C	Modification to Draft Study Programme C.a.k(III) – Communication theory	
III/135	Working Group III-C	Draft Question – The operational use of efficiency factor	
III/136	Working Group III-C	Proposed additions to Draft Report C.q(III) – Some aspects of the application of communication theory	
III/137 and Corr.1	Working Group III-C	Draft Report – Performance of telegraph systems on HF radio circuits	S.P. 43A
III/138	Study Group III	Draft Report – Use of directional antennae in the bands 4 to 27·5 Mc/s	
III/139	Working Group III-B	Draft Report – Single-channel radiotelegraph systems employing forward error correction	Draft S.P.
III/140	Study Group III	Draft Report – Single-channel duplex ARQ telegraph system	
III/141 and Corr.1	Study Group III	Draft Report – Voice-frequency telegraphy on radio circuits	S.P. 43A
III/142	Working Group III-D	Proposed new Report – Models of phase interference fading to be used in connection with studies of efficient spectrum utilization	
III/143	Working Group III-D	Proposed modifications and corrigenda for Draft Report C.t(III)	
III/144	Study Group III	Proposed modifications and corrigenda for Draft Report C.aa(III)	
III/145	Working Group III-D	Proposed modification to Resolution 1	
III/146	Study Group III	Summary record of the third meeting	
III/147	Study Group III	Summary record of the fourth meeting	
III/148	Study Group III	Status of texts	
III/149	C.C.I.R. Secretariat	List of documents issued (III/101 to III/149)	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP III

No.	Title	Final No.
III/1001	Use of diversity on international HF radiotelephone circuits	Rep. 355
III/1002	Use of common-frequency systems on international radiotelephone circuits	Rep. 353
III/1003	Operational ionospheric sounding at oblique incidence	Rep. 357
III/1004	Use of pre-emphasis and de-emphasis for phototelegraph transmission on HF radio circuits	Rep. 352
III/1005	Directivity of antennae at great distances	Rep. 107-1
III/1006	An improved transmission system for HF radiotelephone circuits	Rep. 354
III/1007	Radio systems employing ionospheric - scatter propagation	Rep. 109-1
III/1008	Radiotelephone systems and the use of radio links in international telephone circuits	Rec. 335-1
III/1009	Facsimile transmission of meteorological charts over radio circuits	Rec. 343-1
III/1010	Arrangement of channels in multi-channel single-sideband and independent-sideband transmitters for long-range circuits operating at frequencies below about 30 Mc/s	Rec. 348-1
III/1011	Influence of frequency deviations associated with passage through the ionosphere on HF radiocommunications	Q. 7/III
III/1012	Improvements in the performance of HF radiotelephone circuits	Q. 13/III
III/1013	Operational ionospheric sounding at oblique incidence	S.P. 20A/III
III/1014	Standardization of phototelegraph systems for use on combined radio and metallic circuits	Rec. 344-1
III/1015	Use of common-frequency systems on radiotelephone circuits	Q. 9/III
III/1016	Bandwidth required at the output of a telegraph or telephone receiver	Rec. 338-1
III/1017	Frequency stability required for single-sideband, independent-sideband and telegraph systems to make the use of automatic frequency control superfluous	Rec. 349-1
III/1018	Use of directional antennae in the bands 4 to 28 Mc/s	Rec. 162-1
III/1019	Principles of the devices used to achieve privacy in radiotelephone conversations	Rec. 336-1
III/1020	Factors affecting the quality of performance of complete systems of the fixed service	S.P. 1A/III
III/1021	Factors affecting the quality of performance of complete systems on the fixed services	Rep. 197-1
III/1022	Voice-frequency telegraphy over HF radio circuits	Rep. 19-1
III/1023	Use of radio circuits in association with 50-baud 5-unit start-stop telegraph systems	Rep. 42-1
III/1024	Single-channel duplex ARQ telegraph system	Rep. 350
III/1025	Telegraph distorsion, error-rate	Rep. 200-1

No.	Title	Final No.
III/1026	Efficiency factor	Rep. 351
III/1027	Some aspects of the application of communication theory	Rep. 196-1
III/1028	Unit of quantity of information	Rec. 166-1
III/1029	Frequency-shift keying	Rec. 246-1
III/1030	Automatic error-correcting system for telegraph signals transmitted over radio circuits	Rec. 342-1
III/1031	Arrangement of voice-frequency telegraph channels working at a modulation rate of about 100 bauds on HF radio circuits	Rec. 436
III/1032	Factors affecting the quality of performance of complete systems of the fixed service	Q. 1/III
III/1033	Automatically controlled radio systems in the HF fixed service	Q. 14/III
III/1034	Efficiency factor	S.P. 18A/III
III/1035	Communication theory	Q. 5/III
III/1036	Voice-frequency (carrier) telegraphy on radio circuits	S.P. 17A/III
III/1037	The operational use of efficiency factor	Q. 15/III
III/1038	Efficient use of the radio-frequency spectrum	Rep. 414 *
III/1039	Model of phase interference fading to be used in connection with studies of the efficient use of the radio-frequency spectrum	Rep. 415 *
III/1040	Voice-frequency telegraphy on radio circuits	Rep. 347
III/1041	Remote control signals for facsimile transmissions	Rep. 201-1
III/1042	Performance of systems using phase-shift keying on HF radio circuits	Rep. 346
III/1043	Bandwidths and signal-to-noise ratios in complete systems	Rec. 339-1
III/1044	Distortion characteristics required for single-sideband and independent-sideband systems used for high-speed data transmission over HF radio circuits	Q. 12/III
III/1045	Communication theory	S.P. 5A/III
III/1046	Improved efficiency in the use of the radio-frequency spectrum	Res. 1-1
III/1047	Single-channel simplex ARQ telegraph system	Rep. 348
III/1048	Single-channel radiotelegraph systems employing forward error correction	Rep. 349
III/1049	Use of directional antennae in the bands 4 to 28 Mc/s	Rep. 356
III/1050	List of documents issued (III/1001 to III/1052)	
III/1051	Operating noise-threshold of a radio receiving system	Rep. 413 *
III/1052	Performance of telegraph systems on HF radio circuits	Rep. 345

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* To be published separately.

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RECOMMENDATIONS OF SECTION D (MOBILE SERVICES)

D. 1: General

RECOMMENDATION 258-1 *

SINGLE-SIDEBAND AERONAUTICAL AND MARITIME MOBILE RADIOTELEPHONY SYSTEMS

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

CONSIDERING

(a) that the main advantages of single-sideband systems (SSB), as compared with double-sideband (DSB), for mobile radiotelephony, are as follows:

a.a reduction of bandwidth required per channel;

a.b increase in signal-to-noise ratio, or, alternatively, reduction in transmitter power (and hence antenna voltage), for the same signal-to-noise ratio, improvements dependent upon the degree of carrier suppression;

a.c reduction of the distortion that is due to selective fading;

a.d reduction of interference, particularly that due to beat notes, between carriers dependent on the degree of carrier suppression;

a.e reduction of interference, due to cross-modulation between adjacent channel transmissions;

(b) that the disadvantages of SSB compared with DSB for mobile radiotelephony, are as follows:

b.a more rigorous requirements for transmitter and receiver frequency stability;

b.b greater complexity of apparatus;

b.c higher prices of the equipment;

b.d higher maintenance costs for the equipment;

b.e impracticability of conversion of existing mobile DSB equipment for SSB operation;

b.f Doppler effects, that are significant for very high-speed mobile units;

(c) that the MF-radiotelephony bands, used in the maritime services (i.e. world-wide 1605 to 2850 kHz and additionally, in Region 1, 3155 to 3800 kHz):

c.a include the international calling and distress frequency 2182 kHz;

c.b are shared with fixed services;

c.c are used by many low tonnage ships, some compulsorily and others voluntarily fitted exclusively with DSB MF-radiotelephony equipment;

(d) that the parts of the HF bands (i.e. 4000 kHz to 23 000 kHz for mobile maritime and 2850 kHz to 24 000 kHz for aeronautical use), allocated to the respective services;

d.a do not include any international distress frequency;

* This Recommendation terminates the study of Question 162.

d.b are exclusively allocated to these services;

(e) that in the maritime mobile services, the advantages of SSB operation predominate over the disadvantages;

(f) that although the introduction of class of emission A3J is a desirable objective it may be necessary to use class of emission A3A for public correspondence services for an indefinite period to obtain acceptable a.g.c. performance;

(g) that, in the maritime mobile services, in the interests of safety of life at sea, the introduction of SSB operation should not be allowed to discourage the extension of voluntary fitting of DSB MF-radiotelephony equipment;

(h) that Recommendation No. 3 of the Final Report of the Panel of Experts, set up under Resolution No. 3 of the Administrative Radio Conference, Geneva, 1959, urges introduction of SSB in the maritime mobile HF radiotelephony service;

UNANIMOUSLY RECOMMENDS

1. for the maritime mobile services (see also Appendices 15 and 17 to the Radio Regulations, Geneva, 1959, and Recommendation No. 28 of the Administrative Radio Conference, Geneva, 1959);

1.1 that SSB operation be introduced in the MF and HF radiotelephony bands;

1.2 that coast stations be prepared to communicate with both DSB and SSB ship stations;

1.3 that for SSB equipment the following technical characteristics be employed:

1.3.1 in coast and ship station transmitters facilities should be provided for both class of emission A3A having a carrier reduction of 16 $\pm$ 2 dB below peak envelope power, and class of emission A3J having a carrier reduction of not less than 40 dB below peak envelope power; (Note 1)

1.3.2 the carrier frequency of the transmitters should be maintained within the following tolerances:

1.3.2.1 for coast stations: $\pm$ 20 Hz;

1.3.2.2 for ship stations: short-term limits (of the order of 15 min) $\pm$ 40 Hz;

1.3.2.3 for ship stations: within $\pm$ 100 Hz of the reference value;

1.3.3 the carrier frequency of the receivers should be maintained within the following tolerances:

1.3.3.1 for coast stations: $\pm$ 20 Hz;

1.3.3.2 for ship stations the short-term limits (of the order of 15 min) $\pm$ 40 Hz; (Note 2)

1.3.4 the upper sideband should be used (see Appendix 15, Section B and Appendix 17 of the Radio Regulations, Geneva, 1959); (Note 3)

1.3.5 the channel arrangements should be such, that two SSB channels are accommodated within each existing DSB channel and the bandwidth of the SSB emissions should be kept within such limits as will permit this to be done. (The precise arrangement of these SSB channels is scheduled to be further discussed at the World Administrative Radio Conference, 1967. See also Appendix 17 of the Radio Regulations, Geneva, 1959);

1.3.6 the transmitter audio-frequency band should be 350 to 2700 Hz, with a permitted amplitude variation of 6 dB; (Note 4)

1.3.7 the unwanted frequency-modulation of the SSB carrier should be sufficiently low to prevent harmful distortion;

1.3.8 in the MF maritime mobile radiotelephony bands, SSB ship stations should be able to insert a carrier at a level sufficient to permit satisfactory reception by DSB receivers when communicating with DSB stations;

1.3.9 in the particular case of transmissions on the radiotelephone calling and distress frequency 2182 kHz, all transmissions should be made either by DSB, or by SSB with a carrier level sufficient to permit satisfactory reception by DSB receivers;

1.4 that the attention of Administrations should be drawn to the fact that, there would be technical and operational advantages in designating certain frequencies for international common use for ship-shore and inter-ship working;

2. that for the aeronautical mobile service, the Director, C.C.I.R., should:

2.1 advise the I.C.A.O. of this Recommendation;

2.2 renew the invitation to the I.C.A.O. to advise the C.C.I.R. of any technical and operational problems on which they would like the assistance of the C.C.I.R.;

2.3 offer to keep the I.C.A.O. informed of progress made by the C.C.I.R. in the study of the application of SSB working in the maritime mobile services;

2.4 request the I.C.A.O. to keep the C.C.I.R. informed of progress made by the I.C.A.O. in the study of the application of SSB working in the aeronautical mobile services.

Note 1. – The normal method of operation for each coast station should be indicated in the I.T.U. " List of Coast Stations ".

Note 2. – This value may be maintained either manually or by other means.

Note 3. – Exceptionally, in the bands between 4 and 23 MHz independent-sideband (ISB) may be used by special arrangement between Administrations.

Note 4. – These limits may need to be modified when selective calling is introduced.

RECOMMENDATION 422 *

PULSE TRANSMISSION FOR RADIO DIRECTION-FINDING

The C.C.I.R., (1953 – 1963)

CONSIDERING

(a) that certain studies, extending over many years, of the errors of direction finders show that, under ideal conditions of site, equipment and operation, the use of pulse transmissions offers only a slight improvement in accuracy over the use of continuous-wave transmissions;

(b) that, in practice, unavoidable departures from the ideal conditions referred to in § *(a)* would tend to reduce this improvement in accuracy;

(c) that pulse transmissions occupy wide bandwidths;

* This Recommendation replaces Recommendation 126.

UNANIMOUSLY RECOMMENDS

that the use of pulse transmissions for radio direction-finding at frequencies below 20 000 kHz is generally undesirable.

ANNEX

The following errors in high-frequency direction-finding can occur:

1. observational errors introduced by the operator;
2. instrumental errors, including polarization errors and those due to deficiencies of the direction-finder site;
3. errors due to radiation scattered from topographical features many wavelengths distant from the direction finder;
4. errors due to lateral deviation in the ionosphere;
5. errors due to wave interference caused by convergence of rays and by different modes of propagation.

The advantage of a pulse emission over a continuous-wave emission lies in its ability to allow signals arriving over different paths to be separated, and so to reduce errors arising from sources 4 and 5 above.

The degree of accuracy to be expected from the use of pulse emissions for radio direction finding has been studied, and it is estimated that in most favourable circumstances, for a frequency of about 8000 kHz, the standard deviation of a single rapidly observed bearing might be about 3° for a continuous-wave emission and about 2° for a pulse emission. The corresponding figures for the mean of ten such bearings taken in a period of five minutes are: continuous-wave 2·5°, pulse 1·7°.

RECOMMENDATION 423-1

USE OF 8364 kHz FOR RADIO DIRECTION-FINDING

The C.C.I.R., (1951 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) Nos. 994, 997 and 1179 of the Radio Regulations, Geneva, 1959;

(b) that land stations keep watch during their hours of service on the band 8354 kHz to 8374 kHz of which 8364 kHz is the centre;

(c) that Regulations 12 and 13 of Chapter IV of the Safety of Life at Sea Convention, London, 1960, indicate minimum specifications for automatic distress transmitters;

(d) that tests and operational experience have shown that radio direction-finding at 8364 kHz may be a valuable aid (in conjunction with direction-finding at 500 kHz), in finding the position of both aircraft and ships in distress and survival craft;

(e) that complete coverage cannot be obtained with direction-finding on only one frequency in the HF (decametric) band because of the limitations caused by radio-propagation conditions;

(f) that HF (decametric) radio direction-finding requires apparatus as free as possible from local site error and polarization error;

(g) that the accuracy of the bearing will depend upon the field strength of the signal and the signal/noise ratio;

(h) that in view of the rapid variation of the apparent azimuth of the bearing which is frequently observed in HF (decametric) radio direction-finding, measurements should be made over several minutes to obtain a more accurate mean bearing; and that the bearing and fix may be improved subsequently by a further series of measurements;

(i) that standardized distress transmissions are desirable;

(j) that it is essential to have a means of rapid communication between the watch-keeping station and the direction-finding stations;

UNANIMOUSLY RECOMMENDS

1. that the site of the HF (decametric) radio direction-finding station should be, as far as possible:

1.1 flat and horizontal for a radius preferably of at least 200 m, with the surrounding neighbourhood flat and free from obstruction;

1.2 of high and uniform ground conductivity;

1.3 free from large metallic masses and objects likely to resonate at frequencies near to 8364 kHz;

2. that the antenna system should be as free as possible from wave polarization error (e.g. Adcock systems and spaced-loop systems);

3. that the bandwidth of the direction-finding receiver, used when bearings are taken, should be as narrow as possible, compatible with the modulation and frequency stability of the signal on 8364 kHz and that a broader bandwidth position should also be incorporated in the receiver for watch-keeping purposes;

4. that the sensitivity of the direction-finding equipment should be such that it operates satisfactorily with a field-strength as low as 5 μV/m;

5. that the bearing should be determined by an aural-null method or by any other method of comparable or better accuracy;

6. that the direction-finding equipment should be adjusted, balanced and calibrated at frequent intervals at the frequency of 8364 kHz;

7. that the signal radiated by survival craft should be as strong as possible and stable in frequency to ensure the greatest accuracy in determining the bearings;

8. that the signals transmitted by survival craft should preferably include long dashes sent over a period of not less than five minutes for direction-finding purposes. The attention of Administrations should be drawn to the precise form and content of such signals proposed by France, U.S.A. and the United Kingdom, given in Doc. 39 (France), 43 and 99 (U.S.A.) and 44 (United Kingdom), Geneva, 1951, and to the question of whether it would be desirable to use a common form of signal for both 500 kHz and 8364 kHz;

9. that, to give as great accuracy of fix as possible, several widely-spaced and interconnected direction-finding stations should be employed (see Annex);

10. that the attention of Administrations concerned should be drawn to the advantage of their studying further:

10.1 the most suitable type of network for providing rapid communication between direction-finding stations and plotting centres;

10.2 the most suitable way in which information should be exchanged between different stations or networks (e.g. use of " Q " code);

10.3 the best way to evaluate the most probable fix (position) from bearings supplied by the direction-finding stations;

11. that the attention of Administrations should also be drawn to the fact that world-wide direction-finding coverage cannot be obtained with only one frequency in the HF (decametric) band.

ANNEX

ACCURACY OF BEARINGS AT 8364 kHz

At distances greater than about 1200 km the root-mean-square (r.m.s.) bearing error to be expected with a modern HF (decametric) direction-finding system is of the order of 3° to 5°

At distances less than 1200 km the error progressively increases with decrease of distance to values of the order of 5° to 10°; at small distances, less than about 100 km, the error may be even greater than 10°.

The above figures refer to the arithmetic mean of bearings spread over an interval of not more than about 10 min.

RECOMMENDATION 437 *

PUBLICATION OF THE " CODES AND ABBREVIATIONS FOR THE INTERNATIONAL TELECOMMUNICATION SERVICES " BY THE INTERNATIONAL TELECOMMUNICATION UNION

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

CONSIDERING

(a) that the second edition of the " Codes and Abbreviations for the International Telecommunication Services ", published by the International Telecommunication Union was issued in 1963;

(b) that Administrations have been asked to consider whether there is an operational need for the unification of codes, in accordance with Opinion 20, § 3;

(c) that no Administration has expressed a need for the unification of codes;

(d) that at the Interim Meeting of Study Group XIII of the C.C.I.R., 1965, Administrations agreed that there was, in fact, no operational reason for attempting to unify the codes;

UNANIMOUSLY RECOMMENDS

1. that no further action should be taken concerning the unification of the " Codes and Abbreviations for the International Telecommunication Services ";

2. that the Director, C.C.I.R., be invited to bring this Recommendation to the attention of the Director, C.C.I.T.T.

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* This Recommendation cancels Opinion 20.

D. 2: Maritime mobile service

RECOMMENDATION 45

AVOIDANCE OF INTERFERENCE FROM SHIPS' RADAR TO OTHER RADIOCOMMUNICATION APPARATUS ON BOARD

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

CONSIDERING

(a) that experience has proved that, with well-designed and properly installed radar, the possibility of interference occurring in practice is very remote;

(b) that the possibility of interference to radio reception and to direction-finding on a vessel, other than that upon which the radar is located, is exceedingly remote and that no instances of such interference have been reported;

(c) that, in the unlikely case where radar interference might result to radio reception aboard a radar equipped vessel, the presence of such interference may readily be detected and identified by listening on the radio receiver or direction-finder;

(d) that, where interference has occurred to radio reception aboard ships equipped with well designed radar, in each case the cause of the interference has been faulty initial installation and has been removed by correcting the installation;

UNANIMOUSLY RECOMMENDS

1. that Administrations shall see to it that radar equipment placed aboard ships is well designed and properly installed, so as not to cause interference to radio reception aboard the radar equipped vessel. In this regard, particular attention shall be paid to shielding, bonding and to fitting line filters, especially in the modulator circuits, for the conductors which are routed between the major components of the installation;

2. that the absence of interference shall be assured, either by test procedures of prototypes or by installation inspection procedures, whereby an investigation is made to determine whether or not there exists any noticeable interference to ships' radio receivers or direction-finders, under practical conditions of installation and operation.

RECOMMENDATION 76

VOICE-OPERATED DEVICES FOR SHIP STATIONS AND CARRIER-OPERATED DEVICES FOR SHORE STATIONS

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

CONSIDERING

(a) that the essential characteristics of the devices controlled by voice currents and acting on the carrier wave in radiotelephone stations on board ships and of the carrier-operated devices in receivers of coast stations are their " operate " and " release " times;

(b) that the operate times of the devices should be short to minimize clipping, and their release times should be sufficiently long to enable the devices to remain operated in the intervals between words in normal speech;

UNANIMOUSLY RECOMMENDS

1. that the operate and release times of the voice-operated carrier switching unit on the ship should be as follows:

Input level (Note 1)	Net operate time (Note 2)	Net release time (Note 3)
— 30 dB	less than 25 ms	between 75 and 170 ms
— 20 dB	less than 15 ms	between 75 and 170 ms

2. that the operate time *(Note* 4) of the carrier-operated device in the coast station receiver, should be as short as practicable to allow somewhat longer operate times in the ship's apparatus and should not exceed 5 ms when the carrier level at the input to the receiver is more than 1 dB above the level just necessary to operate the device. The required value of release time *(Note* 5), is dependent on several factors, including the time constants of the automatic gain control of the radio receiver and a value between 10 and 50 ms is generally suitable.

Note 1. – *Input level* refers to the level of a test sinusoidal signal of frequency, corresponding to the middle of the voice-frequency range relative to that producing 100% modulation.

Note 2. – *Net operate time* is the time which elapses between the instant the test signal is applied to the input to the modulator of the transmitter, and the instant when the carrier reaches 50% of its maximum amplitude.

Note 3. – *Net release time* is the time which elapses between the instant when the test signal is disconnected and the instant the carrier is reduced to within 5 dB of the maximum carrier suppression achieved.

Note 4. – *Operate time* of the carrier-operated device is the time which elapses between the sudden application of a test signal simulating the carrier wave from the ship and the instant of opening of the receiving channel (the instant when the attenuation of the receiving channel is within 5 dB of the final value of attenuation for the receiving condition).

Note 5. – *Release time* of the carrier-operated device is the time which elapses between the cessation of a test signal simulating the carrier wave from the ship and the instant of blocking of the receiving channel (the instant when the attenuation of the receiving channel is within 5 dB of the final value of attenuation in the blocked condition).

RECOMMENDATION 77-1

CONDITIONS NECESSARY FOR INTERCONNECTION OF MOBILE RADIOTELEPHONE STATIONS (FOR INSTANCE, AUTOMOBILES, AIRCRAFT AND SHIPS) AND INTERNATIONAL TELEPHONE LINES

The C.C.I.R., (1951 – 1966)

CONSIDERING

(a) that the conditions concerning which international agreement is necessary appear to be few in number;

(b) that these conditions, if met, would permit suitable interconnection between mobile radiotelephone stations and international telephone lines;

UNANIMOUSLY RECOMMENDS

1. that mobile radiotelephone circuits, intended for connection to international telephone systems, should terminate (on a two-wire basis, for the present at least) in such a way that they may be connected to international lines in the same manner as other landline connections;

2. that the mobile radiotelephone circuits should accept from and deliver to the landline system speech volumes conforming, as far as possible, to the C.C.I.R. and C.C.I.T.T. standards for connections to international circuits;

3. that the attenuation-frequency characteristics of the radio system (including the landlines to the radio receiver and radio transmitter) should be such that the grade of transmission is not unduly affected; and, in particular, the effectively transmitted band should be not less than 300 to 2600 Hz (for single-sideband aeronautical and maritime radiotelephone equipment, see Recommendation 258-1, § 1.3.5.);

4. that the noise from a radio circuit, connected to an international circuit, should not be unduly great and should be insufficient to operate echo suppressors or other devices on domestic or international circuits frequently;

5. that, for mobile radiotelephone stations, which may have to communicate with land stations in more than one country, consideration be given to the necessity for agreement as to a method of signalling for use between the land mobile stations.

RECOMMENDATION 218 *

PREVENTION OF INTERFERENCE TO RADIO RECEPTION ON BOARD SHIPS **

The C.C.I.R., (1951 – 1956)

CONSIDERING

(a) that the Maritime Regional Radio Conference, Copenhagen, 1948, recommended that the C.C.I.R. study the question of interference to radio reception caused by electrical installations on board ship;

(b) that the Safety of Life at Sea Conference, London, 1960 (Chapter IV, Regulation 9), requested that all steps be taken to eliminate, as far as possible, the causes of radio interference from electrical and other apparatus on board ship;

(c) that electrical interference is caused by the unwanted excitation of the radio receiving equipment, including the antenna, by fluctuating electromagnetic fields set up by other electrical installations;

(d) that the fluctuation of electromagnetic fields, which gives rise to interference, is caused by abrupt changes in current in the source of interference, and by abrupt changes in the resistance of conductors situated in electromagnetic fields;

(e) that electrical interference may be transmitted by direct radiation and induction from the source of interference itself, and also by re-radiation and induction from conductors which carry interfering currents;

UNANIMOUSLY RECOMMENDS

1. that the design, construction and installation of electrical equipment in ships should be such that interference is minimized at its source (see also No. 959 of the Radio Regulations, Geneva, 1959);

2. that electrical equipment installed in ships should be efficiently maintained to prevent any increase in the level of interference which it causes;

3. that antennae used for transmission or reception should be erected, as far above and as far away as possible from electrical machinery and from parts of the ship's structure such as funnels, stays and shrouds;

4. that the down-leads of antennae which are used exclusively for reception should be screened; that the screen should extend continuously from the receiver to a point which is as high as practicable above the ship's structure, and that the screen should be effectively connected to the earth terminal of the receiver;

5. that frame or loop antennae used for direction-finding, should be effectively screened against electrostatic interference;

6. that the radio receiving room should be effectively screened and situated as high as practicable in the ship;

7. that power converting plant, within the radio receiving room, should be housed in a separate screened enclosure, unless the plant is self-screened;

8. that the radio receiving equipment should be designed so that it is effectively screened;

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* This Recommendation replaces Recommendation 78. Certain references to the Radio Regulations have been inserted subsequently.

** Interference from radar and other electronic equipment has not been specifically considered in framing this Recommendation. The prevention of radar interference is covered by Recommendation 45.

9. that suppressor filters, to prevent the propagation of interference, should be fitted at the sources of interference, preferably built into the interference-producing equipment, and that in particular:

9.1 the electrical ignition systems of internal-combustion engines, including those which may be installed in lifeboats, should be fitted with suppressors;

9.2 the navigational instruments and associated equipment, which are installed in the neighbourhood of the receiving antennae or the radio receiving room should, if necessary, be fitted with suppressors, be screened, and the screen effectively earthed;

10. that cables in the vicinity of the receiving antennae or the radio receiving room, and cables within the radio room, should be screened by enclosing them in metal conduits, unless the cables themselves are effectively screened;

11. that twin cables should be used wherever possible: if single-core cable is necessary, the " lead " and " return " conductors should be fixed, as close to one another as possible, to avoid the formation of loops;

12. that suppressors should be fitted to cables at their point of entry into the radio receiving room, unless they terminate close to the point of entry in equipment which itself provides adequate screening and suppression;

13. that cables, ducts and pipes which do not terminate in the radio receiving room, should preferably not be installed in the radio receiving room; if it is essential for them to pass through the radio receiving room, the ducts and pipes and the screening of the cables should be effectively earthed;

14. that a copper earth-busbar should be fixed along the bulkheads and bonded at several points to the ship's structure and to the metal structure or screening of the radio receiving room; the screens of cables within and near to the radio receiving room, as well as the screens of apparatus in the radio receiving room, should be effectively connected to the busbar;

15. that rigging should be either insulated from or bonded to the ship's structure (stays that are subject to considerable tension can more conveniently be bonded);

16. that, for smaller vessels and those constructed of wood, the principles recommended should be applied as far as is practicable;

17. that particular care should be taken to minimize interference on the frequency bands used for distress, safety and direction-finding in the maritime service;

18. that Administrations should bring the above recommendations to the attention of naval architects, shipbuilders and those responsible for the manufacture, installation and maintenance of electrical equipment.

RECOMMENDATION 219-1

ALARM SIGNAL FOR USE ON THE MARITIME RADIOTELEPHONY DISTRESS FREQUENCY OF 2182 kHz

The C.C.I.R., (1951 – 1953 – 1956 – 1966)

CONSIDERING

(a) that it is desirable and practicable to establish an internationally agreed alarm signal for use on the calling and distress frequency of 2182 kHz (see Art. 36 of the Radio Regulations, Geneva, 1959);

(b) that the alarm signal should be such as to:

– provide reliable operation of automatic alarm equipment;

- provide a distinctive signal, which is readily recognized aurally, when received on a loudspeaker or headphones;
- be capable of being received through interference from speech transmissions, through other kinds of interference, and through noise;
- avoid false responses when received either aurally or by automatic means:
- be capable of being produced by a simple manual device, as well as by automatic means;

(c) that the alarm signal should be such as to permit the construction of alarm equipment which is rugged, dependable, stable in performance, of low cost, of easy production, of long life with a minimum of maintenance, and which can be used with existing maritime radiotelephone equipment;

(d) that to help in clearing the calling and distress frequency channel of emissions from other stations the alarm signal and detecting device should be effective beyond the range at which speech transmission is satisfactory;

(e) that the automatic alarm equipment should be capable of operating, in as short a time as possible, consistent with the avoidance of false responses;

(f) that the results of the further examination of this problem by the Administrations which participated in Study Programme 29, Geneva, 1951, are sufficiently conclusive to determine the essential characteristics of the signal, including tolerances that should be recommended for international adoption;

(g) that it is possible to specify the minimum performance standards for automatic alarm equipment, for both transmission and reception, to such an extent that future progress and development are not hampered;

(h) that it is undesirable that the specification of performance standards for automatic alarm equipment should exceed in scope the requirements already established by international agreement for automatic alarm devices, intended for the reception of the international alarm signal or the international distress signal in radiotelegraphy, normally transmitted on the frequency 500 kHz (see Nos. 1475 and 1476, and Appendix 20, § 1 of the Radio Regulations, Geneva, 1959; and Chapter IV, Regulation 10 of the Convention for the Safety of Life at Sea, London, 1960);

UNANIMOUSLY RECOMMENDS

1. that the alarm signal described below should be adopted internationally, for use on the maritime radiotelephony calling and distress frequency of 2182 kHz;

1.1 the alarm signal shall consist of two substantially sinusoidal audio-frequency tones, transmitted alternately. One tone shall have a frequency of 2200 Hz and the other a frequency of 1300 Hz. The duration of each tone shall be 250 ms;

1.2 the tolerance of the frequency of each tone shall be $\pm$ 1·5%; the tolerance on the duration of each tone shall be $\pm$ 50 ms; the interval between successive tones shall not exceed 50 ms; the ratio of the amplitude of the stronger tone to that of the weaker shall be within the range 1 to 1·2;

1.3 when generated by automatic means, the alarm signal shall be sent continuously for a period of at least 30 s but not exceeding one minute; when generated by other means, the signal shall be sent as continuously as is practicable over a period of approximately one minute;

2. that the automatic-devices, intended for the reception of the alarm signal in question, should fulfil the following conditions:

2.1 the frequencies of maximum response of the tuned circuits, and other tone selecting devices, shall be subject to a tolerance of $\pm$ 1·5% in each instance; and the response shall not fall below 50% of the maximum response for frequencies within 3% of the frequency of maximum response;

2.2 in the absence of noise and interference, the automatic receiving equipment shall be capable of operating from the alarm signal in a period of not less than four and not more than six seconds;

2.3 the automatic receiving equipment shall respond to the alarm signal, under conditions of intermittent interference caused by atmospheric and powerful signals other than the alarm signal, preferably without any manual adjustment being required during any period of watch maintained by the equipment;

2.4 the equipment shall not be actuated by atmospheric or by strong signals other than the alarm signal;

3. that the automatic alarm equipment for both transmission and reception, on the calling and distress frequency of 2182 kHz, shall fulfil the following conditions:

3.1 the equipment shall be effective beyond the range at which speech transmission is satisfactory;

3.2 the equipment shall be capable of withstanding vibration, humidity, changes of temperature and variations in power supply voltage equivalent to the severe conditions experienced on board ships at sea, and shall continue to operate under such conditions;

3.3 the equipment should, as far as practicable, give warning of faults that would prevent the apparatus from performing its normal functions during watch hours;

4. that, before any type of automatic alarm equipment for transmission and reception on the calling and distress frequency of 2182 kHz is approved for use on ships, the Administrations having jurisdiction over those ships should be satisfied by practical tests, made under operating conditions equivalent to those obtaining in practice, that the equipment complies with the provisions of §§ 1, 2 and 3 of this Recommendation.

RECOMMENDATION 224 *

TESTING OF 500 kHz RADIOTELEGRAPH AUTO-ALARM RECEIVING EQUIPMENT ON BOARD SHIPS

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

CONSIDERING

that, it is important for the safety of life at sea, that radiotelegraph auto-alarm receiving installations (including the antenna) are always in good working order on board ships at sea;

UNANIMOUSLY RECOMMENDS

in addition to the requirements of Chapter IV of the International Convention for the Safety of Life at Sea, London, 1960;

1. that all radiotelegraph auto-alarm receiving equipment, for use on the international calling and distress frequency of 500 kHz should, wherever practicable, be provided specifically with means for automatic warning of the following:

1.1 failure of any valve filament, whether the cathode is directly or indirectly heated;

1.2 major variation or sustained failure of any source of voltage which is used for supplying valve elements, where this would seriously affect the proper functioning of the apparatus, as laid down in Chapter IV, Regulation 10 of the said Convention;

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* This Recommendation terminates the study of Question 108. The references to the International Convention for the Safety of Life at Sea, London, 1960, have been inserted subsequently.

1.3 any drop in voltage, or complete failure, of the main power supply to the auto-alarm equipment that would seriously affect the proper functioning of the equipment and where such warning is not already given by other means;

2. that provision should be made for listening to the output of the auto-alarm receiver;

3. that the proper functioning of auto-alarm installations should be checked periodically by listening to signals on the auto-alarm receiver with its normal antenna connected, and by observing similar signals received on 500 kHz on the ship's main receiving installations;

4. that measures should be taken to ensure that the auto-alarm antenna is always in good condition;

5. that the design of auto-alarm equipment should be as simple as possible, consistent with reliable and efficient operation;

6. that, wherever practicable, measures should be taken to permit reception on the auto-alarm installation when the radio direction-finder is being used;

7. that live test transmissions of the radiotelegraph auto-alarm signal should *not* be made.

RECOMMENDATION 257 *

SELECTIVE CALLING DEVICES FOR USE IN THE INTERNATIONAL VHF (METRIC) MARITIME MOBILE RADIOTELEPHONE SERVICE

(Question 3/XIII)

The C.C.I.R., (1959)

CONSIDERING

(a) that selective calling from coast stations to ship stations would expedite handling of traffic, particularly in public correspondence services;

(b) that a selective calling system is faster and more positive than calling by voice;

(c) that it overcomes the disadvantage and annoyance caused by vessels being required to listen to all calls;

(d) that it permits concentration of aural watches on the safety and calling channel 156·80 MHz;

(e) that a selective calling system is not subject to language difficulties;

UNANIMOUSLY RECOMMENDS

1. that a selective calling system for the international VHF maritime mobile radiotelephone service be standardized as soon as possible;

2. that this selective calling system should have an international numbering system for such public correspondence services;

3. that the system and the numbering plan should be capable of providing a sufficient number of individual non-conflicting codes;

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* The reference to the Radio Regulations has been inserted subsequently.

4. that the bandwidth required for the transmission of the code signals should not exceed the maximum permissible emission bandwidth specified by regulations governing the maritime services;

5. that the time required to select and transmit the code signal should be of the shortest possible duration consistent with reliable operation;

6. that the system should be capable of satisfactory operation, with signal-to-noise ratios at least equivalent to the minimum acceptable for satisfactory two-way speech transmission;

7. that the individual signalling combinations must be sufficient for adequately identifying ships using selective signalling, considering that it might be possible to repeat codes in sufficiently separated geographic areas, taking into account ships' itineraries;

8. that the selective signalling, at any given coast station, should not be limited to vessels regularly using that coast station. The numbering system should be planned so as to make this unnecessary;

9. that the number code, assigned to a ship, should be distinctive and should be permanently associated with that ship;

10. that the call should not be prefixed by a long dash or other special signal, to attract attention of vessels not fitted with a selective calling device, as such calls should be made, preferably, on the frequency of the common calling and safety channel 156·80 MHz;

11. that the attention of Administrations should be drawn to the desirability of their reaching agreement upon the channel, or channels, that should be used for selective calling. Attention should also be drawn to Note 8 of Annex 1 of the Agreement on the international VHF maritime mobile radiotelephone service, The Hague, 1957 (see also Nos. 1214 ,1361 and 1362 of the Radio Regulations, Geneva, 1959).

RECOMMENDATION 425

TECHNICAL CHARACTERISTICS OF FREQUENCY-MODULATION VHF (METRIC) MARITIME MOBILE EQUIPMENT

(Questions 107, 161 and 164)

The C.C.I.R., (1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that Nos. 1359 to 1379 inclusive and Appendix 18 of the Radio Regulations, Geneva, 1959, stipulate the general procedure for the world-wide use by the international maritime mobile service in the band 156-174 MHz;

(b) that the use of VHF (metric) equipment in the maritime mobile service could reduce the use of MF (hectometric) maritime bands and thus tend to reduce congestion in these heavily loaded bands;

(c) that the early introduction of the world-wide use of equipment operating at the frequency 156·8 MHz and other channels specified in Appendix 18 of the Radio Regulations, Geneva, 1959, could contribute to the safety of life at sea;

(d) that it would be desirable to reach agreement upon essential technical characteristics for frequency-modulation VHF (metric) radiotelephone equipment for use in international maritime services to expedite the international use of such equipment;

(e) that, in the informal agreement on standardization of VHF (metric) channels for international maritime radiotelephone services that was reached among certain countries during the Baltic and North Sea Radiotelephone Conference, 1955 (see I.T.U. Circular letter 1683/55/R, dated December 1955), it was considered that the equipment should employ frequency-modulation and be capable of operating ultimately with a frequency spacing of 50 kHz;

(f) that, without some further measure of agreement on channel allocations, it is not possible to decide all the technical characteristics needed to facilitate the design of equipment for international VHF (metric) maritime mobile services;

(g) that the International Maritime VHF Radiotelephone Conference, The Hague, 1957, had agreed, among other matters, upon a frequency allocation table using 4·6 MHz separation for duplex operation in the VHF international maritime mobile radiotelephone service;

UNANIMOUSLY RECOMMENDS *

1. that the following characteristics for frequency-modulation VHF (metric) radiotelephone equipment for the international maritime mobile services operating at 156·8 MHz and other channels specified in Appendix 18 to the Radio Regulations, Geneva, 1959, should be adopted by Administrations;

1.1 that, at present, the frequency deviation should not be greater than ± 15 kHz and the maximum deviation should be reviewed later if it is found in practice that unacceptable adjacent channel interference occurs, particularly as the loading of the channels increases;

1.2 that all receivers should be capable of receiving satisfactorily emissions having a maximum deviation of ± 15 kHz;

2. that vertical polarization should be used;

3. that, in the absence of fading and local screening, the protection ratio for common-channel operation should be such that the desired signal level exceeds the interfering signal level by at least 10 dB. Each Administration should provide for a further allowance, where appropriate, for fading and for fluctuations of a local nature (for instance, reflections from the terrain, sea, ships, docks, etc.);

4. that the equipment should be designed for a frequency separation between adjacent channels of 50 kHz;

5. that the frequency separation between the transmitting and receiving frequencies for duplex working should be 4·6 MHz;

6. that further study of the means of selective calling is required. For this purpose, reference is made to Question 3/XIII, Report 320-1 and Resolution 19-1;

7. other essential parameters;

7.1 frequency modulation with a pre-emphasis of 6 dB/octave should be used (phase-modulation) with subsequent de-emphasis in the receiver;

7.2 the output power of the ships' transmitters should generally not exceed 20 W except in special circumstances to be determined by individual Administrations;

7.3 spurious emissions:

7.3.1 the mean power of spurious emissions due to harmonics of the carrier frequency should not exceed 25 μW measured at the antenna terminals of the transmitter when loaded with a resistance equal to the nominal antenna impedance;

* See also Appendices 3, 4 and 19 to the Radio Regulations, Geneva, 1959.

7.3.2 the mean power of spurious emissions falling in any other international VHF maritime mobile channel due to products of modulation should not exceed 10 μW, measured at the antenna terminals of the transmitter or receiver when loaded with a resistance equal to the nominal antenna impedance;

7.3.3 the mean power output of any other spurious emission on any discrete frequency within the international VHF maritime mobile band should not exceed 2·5 μW, measured at the antenna terminals of the transmitter or receiver when loaded with a resistance equal to the nominal antenna impedance;

7.3.4 in cases where Administrations permit exceptionally the use of higher powered transmitters, proportionate increases in the level of these spurious emissions may be permitted.

7.4 the audio-frequency bandwidth should be limited to 3000 Hz;

7.5 the frequency tolerance of the transmitter should not exceed 0·002%;

7.6 to minimize interference, special attention should be paid to the following receiver characteristics:

- stability,
- selectivity,
- receiver radiation,
- intermodulation;

8. equipment should be designed so that frequency changes between assigned channels can be carried out rapidly, e.g., within a few seconds;

9. that care should be taken in the choice of intermediate frequencies for VHF receivers to avoid interference from other services and, in particular, care should be taken to avoid interference from other maritime mobile services, especially those in the 500 kHz and 2 MHz bands.

RECOMMENDATION 427 *

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE VHF (METRIC) MARITIME MOBILE RADIOTELEPHONE SERVICE

(Question 164)

The C.C.I.R., (1959 – 1963)

CONSIDERING

(a) that intermodulation products may cause serious interference in the operation of the VHF mobile maritime radiotelephone service;

(b) that intermodulation products may be generated and radiated at receiving stations and transmitting stations, in the radio equipment itself or at external points (such as antenna systems), where there is electrical non-linearity;

(c) that practical measures can be taken to minimize the generation of such intermodulation products and to mitigate their harmful effects;

* *This Recommendation replaces Recommendation 256.*

UNANIMOUSLY RECOMMENDS

1. that Recommendation 218, particularly §§ 3, 4 and 15, should be followed for the purpose of minimizing the generation of intermodulation products at points on ships external to the receiver;

2. that antennae, rigging, stays and structures, likely to cause intermodulation products, should be maintained in such condition as to minimize the generation of intermodulation products;

3. that care should be taken, in the design and development of receivers, to minimize the possibility of interference due to the generation of intermodulation products in the receivers themselves;

4. that the range of interference, due to radiated intermodulation products, should be limited to sea areas that are not normally navigated by ships and to shore areas that are clear of coast receiving stations;

5. that the siting of coast stations should take into account the factors mentioned in § 4 above (see also No. 695 of the Radio Regulations, Geneva, 1959);

6. that frequency assignments in the VHF mobile maritime radiotelephone band should, as far as possible, take into account the possibility of interference from intermodulation products (see also No. 695 of the Radio Regulations, Geneva, 1959);

7. that where the service area permits, coast stations should use directive antennae (see also No. 695 of the Radio Regulations, Geneva, 1959);

8. that care should be taken in the use of the single-frequency channels to minimize interference, due to intermodulation products, to the common calling and safety channel of 156·80 MHz and to the other channels specified in Appendix 18 to the Radio Regulations, Geneva, 1959 (see also No. 1363 of the Radio Regulations, Geneva, 1959);

9. that frequency assignments to other services should, as far as possible, take into account the possibility of interference to the VHF mobile maritime radiotelephone service due to the generation of intermodulation products; in particular, powerful emissions from stations near coastal areas and with frequencies differing by about 4·6 MHz from one another, should be avoided if possible.

RECOMMENDATION 428-1

DIRECTION-FINDING IN THE 2 MHz BAND ON BOARD SHIPS

(Question 2/XIII)

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

CONSIDERING

(a) that, according to the Convention for the Safety of Life at Sea, London, 1960, the medium frequency radiotelephony calling and distress frequency of 2182 kHz will become of increasing importance to the safety of life at sea;

(b) that, in most distress cases, merchant ships and fishing vessels and other surface craft participate in search and rescue;

(c) that in addition to ships between 500 and 1600 tons gross tonnage, which are already required to be fitted with medium frequency radiotelephone equipment if they do not carry medium frequency radiotelegraph equipment, ships between 300 and 500 tons gross tonnage will also be required to fit such equipment, in accordance with Chapter IV, Regulation 4 of the Convention for the Safety of Life at Sea, London, 1960;

(d) that a large number of ships of more than 1600 tons gross tonnage (which are compulsorily fitted with medium frequency radiotelegraph equipment), are voluntarily fitted with medium frequency radiotelephone equipment and that the number of such ships is increasing;

(e) that the majority of deep-sea fishing vessels are fitted voluntarily with medium frequency radiotelephone equipment;

(f) that an increasing number of ships are being fitted with direction-finding equipment capable of taking bearings in the 2 MHz band;

(g) that direction-finding and especially homing by ships is important in cases of distress;

(h) that Recommendation No. 31 of the Convention for the Safety of Life at Sea Conference, London, 1960, drew the attention of contracting governments to the studies being undertaken under Question 2/XIII by the C.C.I.R.,

(i) that technical studies in several countries have shown:

i.a that direction-finding, or at least homing, is usually possible in the 2 MHz band on many ships;

i.b that compared with the problems of direction-finding by ships in the lower parts of the medium frequency band, the main cause of error in direction-finding in the 2 MHz band is re-radiation from various parts of the ship's super-structures, masts, downleads, halyards, stays, derricks, etc., and from other antennae;

i.c that errors caused by re-radiation effects, however, should be constant if the disposition and electrical conditions of the re-radiators are constant and that such errors can be taken into account by calibrating the direction-finder;

i.d that direction-finding and homing is easier on board small ships than on larger ones, because an increase in the size of ships and their superstructures, masts, etc., as given in § *i.b,* leads to an increase of disturbing resonance effects;

i.e that a reliable direction-finder calibration can be more readily obtained if it is restricted to a specific frequency such as 2182 kHz, instead of a wide frequency band;

i.f that even where omnidirectional direction-finding, even on a specific frequency, is difficult or impossible (such as on board large vessels with strong re-radiation effects), homing will nearly always be possible;

UNANIMOUSLY RECOMMENDS

1. that the following technical measures and precautions should be observed when installing direction-finders capable of taking bearings in the 2 MHz band:

1.1 the antenna system, including the sense antenna, of the direction-finder should be erected as far as possible away from any re-radiators;

1.2 the direction-finder antenna system should, preferably, be installed on the fore-and-aft line of the ship;

1.3 if the direction-finder antenna system is fitted on a mast, it should, preferably, be installed symmetrically on top of the mast and not to one side of it;

1.4 if the resonnance frequency of a mast and its rigging is within approximately $\pm$ 20% of the frequency used for direction-finding, then the antenna system of the direction-finder should not in general be mounted on or near the top of the mast, unless the antenna system is one which is not influenced by the mast resonance. The calculation or assessment of the resonance frequency should take into account the effect of the antenna system of the direction-finder;

1.5 that the sense antenna should be mounted on or as near as is practicable to the central axis of the antenna system of the direction-finder;

1.6 the effects caused by re-radiating antenna wires can be minimized by providing properly located isolating switches for the antennae;

1.7 re-radiation from the rigging (e.g. stays, wire ropes, etc.) should be reduced by the insertion of insulators such that the resonance frequency of the longest portion is considerably above the highest frequency used for direction-finding;

1.8 the formation of " closed loops ", e.g. by the rigging, should be avoided by inserting insulators at appropriate points;

1.9 to avoid electrically-doubtful connections, the connecting points of movable parts of the rigging, and connections between masts and derricks, wire ropes, etc., should be short-circuited as far as possible;

2. that the following measures and precautions should be observed in the calibration of direction-finders for the 2 MHz band:

2.1 the rigging, downleads, derricks, halyards, etc., should be in their sea-going positions;

2.2 any antennae that affect the direction-finder should, preferably, be isolated and other antennae which cannot be isolated (for example, because of operational requirements), should be in the same condition as they will be when bearings are being taken at sea; the condition and electrical arrangement of all antennae should be noted on the direction-finder calibration charts;

2.3 calibration should be carried out in an area well clear of the shore and of other ships. If a shore-based transmitter is used, calibration should be carried out on a line passing through that station and crossing the coast-line approximately at right angles. The transmitting antenna should radiate vertically polarized waves from a single element, and care should be taken to avoid re-radiation from any object in the vicinity. The distance between the transmitting antenna and the direction-finder should be great enough to avoid the calibration being affected by the induction field of the transmitting antenna;

2.4 care should be taken to ensure that the direction-finder gives the correct sense on all bearings and frequencies concerned;

2.5 the direction-finder calibration should, as a general rule, cover the full 360° and, as far as possible, should be made at sufficiently small bearing intervals (say, in steps of a few degrees), to detect any sudden changes in the calibration curve (for example, re-entrant portions where two or more different corrections exist for the same indicated bearing);

2.6 calibration at 2182 kHz should be carried out at a frequency as near as possible to 2182 kHz, special attention being paid to No. 1325 of the Radio Regulations, Geneva, 1959, and to the avoidance of interference to established operations in adjacent channels;

3. that the calibration should be checked periodically, especially if the condition of the rigging, etc., has been altered since the last calibration;

4. that on board ships equipped with a direction-finder, the frequency range of which includes the 2 MHz band, a calibration should be made to determine if the direction-finder could be used without modification for omnidirectional direction-finding, or at least for homing on the frequency of 2182 kHz;

5. that when Administrations encourage the use of direction-finders on board ship, capable of operating in the 2 MHz band, or at least on the international radiotelephony distress and calling frequency of 2182 kHz, they should also encourage the provision of suitable facilities for the calibration of such direction-finder equipment;

6. that the Director, C.C.I.R. should be invited to bring this Recommendation to the attention of the I.M.C.O. Reference is made to Recommendation No. 31 of the Convention for the Safety of Life at Sea, London, 1960;

7. that Administrations should bring the above Recommendations to the attention of those responsible for the provision, installation, and maintenance of direction-finders on ships;

8. that Administrations should continue the study of Question 2/XIII.

ANNEX

When the above precautions and technical measures have been taken, under good conditions an accuracy of about ± 2° can be attained in taking bearings in the 2 MHz band by reception of " ground " waves on board ships of less than about 800 tons gross tonnage. In unfavourable conditions, for example, when the ship is pitching and rolling, an accuracy of about ± 5° can be obtained. On larger ships, the accuracy may be worse, but in most cases it should usually be possible to use the direction-finder for homing purposes on 2182 kHz. Bearings taken by reception of skywaves, although variable in azimuth and sharpness, are useful for homing into the ground wave range by utilizing their average value.

RECOMMENDATION 429-1

INTERFERENCE LEVEL ON THE RADIOTELEGRAPH DISTRESS FREQUENCY

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that the Safety of Life at Sea Conference, London, 1960, adopted the following Recommendation (No. 27):

" The Conference, recognizing that at present there is a tendency to increase the maximum power of radiotelegraph installations, and that this may lead to an increase in the interference level on the radiotelegraph distress frequency, which may considerably impair the use of this frequency for safety purposes, recommends that the International Telecommunication Union should be invited by the Organization – (i. e. Intergovernmental Maritime Consultative Organization) – to consider what measures can be taken to prevent such an increase in the interference level ";

(b) the provisions of the relevant Radio Regulations, Geneva, 1959;

(c) the experience of coast station radio operators and ships' radio officers;

UNANIMOUSLY RECOMMENDS

1. that the following measures should be taken to reduce interference at 500 kHz;

1.1 messages prefixed by the Safety Signal, TTT, should be sent on a working frequency after an initial announcement at 500 kHz in accordance with Nos. 1107 and 1492 of the Radio Regulations, Geneva, 1959;

* This Recommendation terminates the study of Study Programme 171.

1.2 coast stations should use their working frequencies to reply to calls from ships at 500 kHz, in accordance with Nos. 1116 and 1117 of the Radio Regulations, Geneva, 1959;

1.3 coast stations making calls to ships at 500 kHz should request ships to reply on their working frequencies, as permitted by Nos. 1023 and 1116 of the Radio Regulations, Geneva, 1959;

1.4 No. 1092 of the Radio Regulations, Geneva, 1959, which forbids " CQ " calls to be made in congested areas, should be enforced by Administrations;

1.5 greater use should be made of the facilities provided under No. 972 of the Radio Regulations, Geneva, 1959, for reducing power at ship stations, and coast stations as far as practicable should use the minimum necessary power, particularly at night, in accordance with No. 694 of the Radio Regulations, Geneva, 1959;

1.6 steps should be taken by Administrations to prevent unnecessary signalling at 500 kHz, particularly during distress, in accordance with Nos. 693, 1107 to 1113 inclusive, and 1445 of the Radio Regulations, Geneva, 1959;

1.7 for Class A2 emissions at 500 kHz the note frequencies used by various stations should, as far as practicable, be spread over the range 450 to 1350 Hz;

1.8 prolonged calling at 500 kHz by ships endeavouring to establish contact with distant coast stations should be avoided by greater use of HF channels or by relaying of messages;

1.9 in areas where considerable use is made of 500 kHz for calls and replies, the calling frequencies assigned to coast stations should be spread over the band 497 to 503 kHz in accordance with No. 1115 of the Radio Regulations, Geneva, 1959;

1.10 in Regions 1 and 3, the frequency of 512 kHz may be used as a supplementary frequency for calls and replies when 500 kHz is being used for distress, in accordance with Nos. 1125 to 1129 inclusive of the Radio Regulations, Geneva, 1959.

RECOMMENDATION 438 *

USE OF CLASSES OF EMISSION A2H AND A3H ON THE DISTRESS FREQUENCIES 500 kHz AND 2182 kHz RESPECTIVELY

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

CONSIDERING

(a) that, for distress and safety purposes, the Convention for the Safety of Life at Sea (SOLAS) prescribes the use of classes of emission as assigned by the Radio Regulations, Geneva, 1959, (SOLAS London, 1960, Chapter IV, Regulations 9 (*e*), 9 (*h*) (*i*), 12 (*b*), 12 (*f*), 13 (*c*), 13 (*f*), 15 (*b*) and 15 (*f*));

(b) that for distress and safety purposes, the Radio Regulations, Geneva, 1959, prescribe for ships and survival craft:

- Class A2 emission at 500 kHz (see Nos. 974, 994, 995 and 1134);

- Class A3 emission at 2182 kHz (see Nos. 984, 994, 996 and 1337);

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* This Recommendation terminates the study of Question 273, and should be brought to the attention of the Maritime World Administrative Radio Conference of the I.T.U., 1967.

(c) that, to the maximum extent possible, amplitude-modulation systems should use single-sideband (SSB) emissions having characteristics in accordance with the relevant C.C.I.R. Recommendations (No. 670 of the Radio Regulations, Geneva, 1959) and that SSB operation be introduced as far as operationally required for radiotelephony in band 6 and band 7 (Recommendation No. 28 of the Administrative Radio Conference, Geneva, 1959);

(d) that in several countries, new marine transmitters are being designed which make use of SSB techniques;

(e) that SSB transmitters may easily and economically be adapted for Class A2H and Class A3H emission;

(f) that unless SSB emission is universally adopted in the MF maritime mobile service, there will be a need for communications between DSB and SSB stations;

(g) that practical and laboratory tests have proved that class of emission A2H on 500 kHz is as effective as class of emission A2, and class of emission A3H at 2182 kHz is as effective as class of emission A3 for alarm, distress, urgency and safety signals when received by stations equipped for DSB reception by aural means or automatic receiving equipment;

UNANIMOUSLY RECOMMENDS

1. that for alarm, distress, urgency and safety signals class of emission A2H at 500 kHz should be considered as effective as class of emission A2.

Note. – To ensure the correct operation of all types of radiotelegraphy automatic alarm equipment, both the carrier and modulating tone should be keyed;

2. that for alarm, distress, urgency and safety signals class of emission A3H at 2182 kHz should be considered as effective as class of emission A3.

RECOMMENDATION 439

EMERGENCY POSITION-INDICATING RADIO BEACONS OPERATING AT THE FREQUENCY 2182 kHz

(Question 318)

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

CONSIDERING

(a) Recommendation No. 48 of the International Conference on Safety of Life at Sea, London, 1960;

(b) Report of the Inter-Agency Working Group, June, 1962, on Coordination of Safety at Sea and in the Air, reproduced in Doc. 393, Geneva, 1963;

(c) the Resolution A. 91 (IV), adopted on 27 September 1965 by the Fourth Session of the Assembly of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) and reproduced in Doc. XIII/71, 1963–1966;

(d) the Report of the Fourth Air Navigation Conference of the International Civil Aviation Organization (I.C.A.O.) (Montreal, 9 November – 3 December, 1965) and reproduced in Doc. XIII/103, 1963–1966;

(e) that there is an urgent need for a beacon to indicate the position of survivors and to facilitate search and rescue operations at sea,

(f) that ships compulsorily fitted for radiotelephony are required to keep continuous watch at the frequency 2182 kHz (see Regulation 7, Chapter IV of the International Convention for the Safety of Life at Sea, London, 1960);

(g) that it is desirable for the beacon signal to be received on the loudspeakers of the receiver which is equipped with filters for the two-tone alarm signal (1300 Hz and 2200 Hz respectively) and which is used for watch-keeping at 2182 kHz. This alarm signal is described in Recommendation 219-1 and Recommendation No. 33 of the International Conference of Safety of Life at Sea, London, 1960;

(h) that the type and sequence of the signal to be transmitted by the beacon should facilitate homing by ships as well as by SAR aircraft taking into account their different speeds;

(i) that the signal emitted by the beacon should as far as practicable be clearly distinguishable from the radiotelephone alarm signal transmitted by ships still afloat or by portable radio apparatus;

(j) that the signal emitted by the beacon should not create harmful interference to other distress calls and messages;

(k) that in the interest of high reliability and minimum expense the electronic and mechanical design of the beacon and especially of its keying device should be as simple as possible;

(l) that national and international trials under operational conditions have already been carried out successfully with such beacons;

UNANIMOUSLY RECOMMENDS

1. that emergency position-indicating radio beacons operating at the frequency 2182 kHz should be divided into two classes;

1.1 low-power beacons designated “ Type L ” producing a field strength equal to or less than 10 µV/m at a distance of 30 nautical miles at sea level;

1.2 high-power beacons designated “ Type H ” producing a field strength greater than 10 µV/m at a distance of 30 nautical miles at sea level;

2. that for both classes of beacon, class of emission A2 should be used;

3. that for both classes of beacon, the depth of modulation should be between 30% and 90%;

4. that the keying signal for “ Type L ” beacons should consist of a keyed emission modulated by a tone of 1300 Hz (± 20 Hz) having a ratio of the period of the emission to the period of silence equal to or greater than 1, and an emission duration between 1 and 5 s;*

5. that the keying signal for “ Type H ” beacons should either consist of the radiotelephone alarm signal (Radio Regulations, No. 1465) or be the same as in § 4 above; if the radiotelephone alarm signal be used, the Morse letter “ B ” and/or the call sign of the ship to which the beacon belongs, should be included by keying a carrier modulated by a tone of 1300 Hz (± 20 Hz) or of 2200 Hz (± 35 Hz);*

6. that for “ Type L ” beacons, the keying signal should be transmitted continuously;

* Beacons carried by ships of the U.S.A. may use, instead of the signals given in §§ 4 and 5, a tone sweeping from 1400 Hz to 300 Hz not faster than twice a second.

7. that for " Type H " beacons, the keying cycle should consist alternately of the keying signal having a duration between 30 and 50 s, followed by a period of silence having a duration between 30 s and 60 s;

8. that the keying cycles given in §§ 6 and 7 may be interrupted by speech transmission if Administrations permit such an additional facility;

9. that the minimum initial field strength produced by " Type L " beacons should be 2.5 μV/m at a distance of 30 nautical miles at sea level;

10. that after a period of 48 hours continuous operation the radiated power should not be less than 20% of the initial power;

11. that the beacons should be designed for the following temperature ranges:
- when stowed, at least −20°C to + 55°C;
- when operating in the open air, at least −10°C to + 45°C;
- when operating afloat, at least −3°C to + 35°C (water temperature);

Note. – Exceptionally, for radio beacons carried by ships operating in limited areas only, other temperature ranges may, due to special conditions in such areas, be accepted.

12. that if the beacons are designed to come into operation automatically when floating, then overriding facilities should be provided to enable them to be switched on and off manually;

13. that beacons should be tested about every 12 months, care being taken to ensure that false alarms are not caused by radiating the signal;

14. that primary batteries for the beacons should have a minimum storage life of about 2 years, and primary batteries in the beacons should be replaced at intervals of about half the storage life;

15. that the mechanical design of the beacons should be such that it is small, light-weight, floatable, watertight and shock-resistant;

16. that the Administrations be invited to make provision in the Radio Regulations for the operation of emergency position-indicating radio beacons at the frequency of 2182 kHz;

Note 1. – The Director, C.C.I.R. is requested to transmit this Recommendation to the Intergovernmental Maritime Consultative Organization (I.M.C.O.) and to the International Civil Aviation Organization (I.C.A.O.).

Note 2. – This Recommendation, together with Opinion 25 terminates the study of Question 318 and cancels Opinion 21.

RECOMMENDATION 440

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

(Question 5/XIII)

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

CONSIDERING

(a) that there is a requirement for communication in the maritime mobile service by means of direct-printing telegraph techniques for exchanging message and data information;

(b) that various systems have already been proposed to meet this requirement and tests have been carried out by different Administrations (see Report 361);

(c) that further systems, especially forward acting error indicating and correcting systems, may be proposed;

(d) that, therefore, it is not yet possible to recommend a specific system to be applied in the maritime mobile service;

(e) that whilst Study Group III has to deal with such systems from the point of view of the fixed services, Study Group XIII has to consider the special aspects concerning their application in the maritime mobile service;

(f) that it is expected that direct-printing telegraph systems will be introduced into the maritime mobile service between the World Administrative Radio Conference, 1967, and a subsequent Administrative Radio Conference;

(g) that the World Administrative Radio Conference, 1967, may need guidance in planning the appropriate radio channels;

UNANIMOUSLY RECOMMENDS

1. that a direct-printing telegraph system for the maritime mobile service should be suitable for:

1.1 exchanging messages and low-speed data information between two stations, i.e. between a coast station and a ship station or between two ship stations; and

1.2 broadcasting from one station to several other stations, i.e. from a coast or ship station to several other stations;

2. that the system should accept signals conforming to C.C.I.T.T. Code No. 2 and should provide similar signals at its output for extension to the Public Telegraph Network (see I.T.U. List of Definitions, Part I, Item 01.12) and vice versa;

3. that bearing in mind the variations in the propagation path, the lowest modulation rate compatible with the grade of service required should be used; in any case it should not exceed 100 bauds;

4. that, bearing in mind that the bandwidth required per communication channel need not exceed 340 Hz and that some Administrations may require more than one channel, the World Administrative Radio Conference, 1967, should consider allocating to Administrations, for this service, blocks of frequencies not exceeding 1·5 kHz wide;

5. that the performance of the system should provide a sufficiently small character error-rate to meet operational requirements but shipborne equipment should not be unduly complex.

D. 3: Land mobile service

No Recommendations in this Sub-section.

D. 4: Aeronautical mobile service

RECOMMENDATION 441

SIGNAL-TO-INTERFERENCE RATIOS AND MINIMUM FIELD-STRENGTHS REQUIRED IN THE MOBILE SERVICES

Aeronautical mobile services above 30 MHz

(Question 1/XIII)

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

CONSIDERING

(a) that the Administrative Radio Conference, Geneva, 1959, in Recommendation No. 3, invited the C.C.I.R. to continue its study of signal-to-interference ratios and minimum field-strengths;

(b) that there are partial data relating to interference protection ratios and minimum field-strengths required in certain documents of conferences of the I.T.U., such as those of the Final Acts of the International Administrative Aeronautical Radio Conference, Geneva, 1948-1949;

(c) that the International Civil Aviation Organisation have adopted standards and recommended practices for the best use of VHF frequencies and the avoidance of harmful interference;

UNANIMOUSLY RECOMMENDS

that the provisions made by the International Civil Aviation Organisation should be considered as adequate for the planning and protection of aeronautical mobile (R) service frequencies above 30 MHz; the provisions are contained in Annex 10, Chapter 4, § 4.1.5 to the Convention of International Civil Aviation, supplemented by the instructions contained in the attachment A to Part II of the same document.

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REPORTS OF SECTION D (MOBILE SERVICES)

D. 1: General

REPORT 93 *

HF (DECAMETRIC) AND VHF (METRIC) DIRECTION-FINDING **

(Question 159)

(1956)

1. Introduction

Two documents, 67 (United States of America) and 232 (United Kingdom), were submitted to the VIIIth Plenary Assembly in response to Question 106. A summary of these two documents, and of the discussion on them, is given below.

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

The United Kingdom document expresses bearing accuracies in the form of errors that are exceeded on only 1 occasion in 20 and the U.S.A. document gives the standard deviation error. For ease of comparison of results, all accuracies have been expressed in a common form in this Report.

2. Accuracy of HF (decametric) bearings

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

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

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

3. Accuracy of VHF (metric) bearings

In the United Kingdom, the 95% error of VHF aeronautical direction-finding stations is generally about 5°, but in the U.S.A. it has been found that the 95% error is usually

* This Report was adopted unanimously.

** See also Appendix 23 to the Radio Regulations, Geneva, 1959.

about 12° on transmissions from aircraft. The difference is probably due mainly to the effects of differences of siting, since with refinements in siting, the 95% error is reduced to about 4° in the U.S.A. At long ranges, beyond the normal service area, VHF direction-finding bearings in the U.S.A. have been found to be sporadic but the accuracy is sometimes as good as 6°.

4. Accuracy of HF (decametric) position fixing

The accuracy of position fixing depends principally on the " geometry " of the direction-finding network, its size and its disposition with respect to the transmitting station concerned, the degree to which the various stations can take simultaneous bearings and act in unison, and the number of stations in the network. The greatest accuracy is obtained when the most probable position of the transmitting station can be evaluated statistically, although in certain applications it is recognised that statistical evaluation may not be practicable or of operational importance. The accuracy of a direction-finding fix can be expressed in terms of the size, position and orientation of the ellipse in which the transmitting station lies with a given probability. Various methods for deriving and plotting probability ellipses are given in the references in Doc. 232, Warsaw, 1956.

5. Accuracy of VHF (metric) position fixing

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

6. Classification of bearings in general

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

7. Classification of HF (decametric) bearings

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

Class A – Bearing appears GOOD, meeting the following requirements:

(1) strong signal,

(2) definite indication (sharp null, etc.),

(3) negligible fading,

(4) negligible interference,

(5) less than 3° of arc of bearing swing,

(6) observed repeatedly for an adequate period of time.

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

(1) marginal signal strength,

(2) blurr (blunting) of indication,

(3) fading and/or audio distortion,

(4) light interference,

(5) more than 3° but less than 5° of arc of bearing swing,

(6) short observation time.

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

(1) inadequate signal strength,

(2) severe blurr (blunting) of indication,

(3) severe fading and/or audio distortion,

(4) strong interference,

(5) more than 5° of arc of bearing swing,

(6) insufficient observation time.

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

Class A: Probability of less than 1 in 20 that the error exceeds 2°,

Class B: Probability of less than 1 in 20 that the error exceeds 5°,

Class C: Probability of less than 1 in 20 that the error exceeds 10°,

Class D: Bearings whose accuracy is less than that of Class C.

8. Classification of VHF (decametric) bearings

It was considered that time alone prevents the classification of VHF bearings taken on transmissions from aircraft and it is not possible for the operator to classify bearings. But the United Kingdom suggested that it would be helpful if VHF aeronautical *stations* were classified, based upon flight-checking procedures. All bearings would then be given the classification of the station, unless they were taken under conditions inferior to those under which the station was calibrated.

9. Classification of HF (decametric) position-fixes

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

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

10. Classification of VHF (metric) position-fixes

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

Classification	Limit of area
Good	4 km, radius, or less
Fair	8 km, radius, or less
Poor	12 km, radius, or less
Estimated	more than 12 km radius

11. Aeronautical aspects

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

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

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

ANNEX

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

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

Type of site	3 MHz		6 MHz		9 MHz	
	Single snap bearing	Mean of 10 bearings taken in 5 min	Single snap bearing	Mean of 10 bearings taken in 5 min	Single snap bearing	Mean of 10 bearings taken in 5 min
Very good	7	6	6	5	6	4
Good, average	10	9	8	7	7	6

REPORT 358 *

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS AND MINIMUM FIELD STRENGTHS REQUIRED IN THE MOBILE SERVICES **

(Question 1/XIII)

(1966)

1. The following documents were submitted to the XIth Plenary Assembly, Oslo, 1966, in reply to Question 272 (subsequently designated Question 1/XIII):

   Doc. XIII/25 (United Kingdom)

   Doc. XIII/41 (F.R. of Germany)

   Doc. XIII/88 (Japan)

   Doc. XIII/95 (I.R.F.B.)

2. VHF and UHF maritime and land mobile services

Man-made noise and natural noise have not been considered in this section.

2.1 The signal-to-interference protection ratios given in Table I were tentatively suggested for VHF and UHF maritime and land mobile services.

TABLE I

Wanted emission	Unwanted emission	RF protection ratio (dB)
F3	F3	8
F3	A3	7
A3	F3	17
A3	A3	19

This Table is based on the degradation of the wanted signal at the output of the receiver from a signal-to-noise ratio of 20 dB to a signal-to-noise plus interference ratio of 14 dB. The Table is based on interference transmission as follows:

- for class of emission A3, 70% modulation by a tone of 1000 Hz;
- for class of emission F3, a frequency deviation of 70% of the maximum by a tone of 1000 Hz, the receiver passband being adapted to the deviation used and the information transmitted.

Under these conditions, class of emission A3 requires protection ratios about 10 dB higher than F3.

2.2 The median values of the field strengths to be protected, for an average grade of service, are given in Table II.

The values given in Table II take into account receiver sensitivities, antenna effectiveness and feeder losses over the various frequency bands.

* This Report was adopted unanimously.

** The aeronautical mobile service above 30 MHz is dealt with in Recommendation 441.

TABLE II

Frequency band (MHz)	Median value of the field strength to be protected (dB rel. 1 μV/m)
30 to 50	8
50 to 100	14
100 to 200	20
400 to 470	28

Higher grades of service, such as those normally provided for connection to the public telephone network, may require to be protected for 90% of time and location. The relevant field strengths can be derived from the curves given in Recommendation 370-1 and Report 244-1.

2.3 Some information on protection ratios and minimum field strength may also be found in the " Special Agreement between the Administrations of Belgium, the Netherlands and the Federal Republic of Germany relating to the use of metric and decimetric waves for fixed and mobile services in border areas, Brussels, 1963 ", and in the Final Acts of the Special Regional Conference, Geneva, 1960.

2.4 Doc. XIII/88 (Japan), 1963-1966 also deals with the above questions for signal-to-noise ratios of 30 and 40 dB at receiver output.

3. HF maritime mobile service

In Doc. XIII/95 (where the expected values of natural noise and of man-made noise at a quiet receiving location have been taken into account), the I.F.R.B. gave an extract from the Technical Standards used by the Board when examining, in accordance with Article 9 of the Radio Regulations, notices of frequency assignments to coast stations in the HF bands.

It indicated for both radiotelephony and radiotelegraphy the protection ratio values which it applies and the minimum field strength to be protected, in characteristic maritime areas.

The purpose was to inform Administrations, as the World Administrative Maritime Radio Conference, 1967, draws near, of the Technical Standards used by the Board.

4. Conclusions

Considerable additional work concerning §§ 2 and 3 is necessary to determine more fully the appropriate protection ratios and the values of the field strengths to be protected, and also to determine and record the measurement methods which should be adopted.

D. 2: Maritime mobile service

REPORT 318 *

MARINE IDENTIFICATION DEVICES

(Question 158)

(1956 - 1963)

1. General

Two documents, 53 (United Kingdom) and 71 (United States of America), were submitted to the VIIIth Plenary Assembly in answer to Question 105 on the identification of a response on a marine radar display.

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

2. Nature of the problem

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

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

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

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

3. Summary of Doc. 53 (United Kingdom)

3.1 *Harbour radar identification*

It was considered that suitable devices of the transponder type might facilitate the movement of vessels in the approaches to a port or in a harbour, so that the echo of the ship could be identified on the harbour radar and communication established as required. Identification

* This Report, which replaces Report 92, was adopted unanimously.

in range and bearing would be essential, so that identification, by the use of normal direction-finding (bearing only), would not normally be sufficient. There is less likelihood of confusion in harbour radar identification, because ships would be identifying themselves to a single harbour radar.

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

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

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

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

3.2 *Inter-ship radar identification*

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

4. Summary of Doc. 71 (United States of America)

4.1 Doc. 71 (United States), Warsaw, 1956, is based upon limited experience in the use of marine radar identification devices but also covers considerable study of the problem by the R.T.C.M., whose report thereon is attached to the document cited as Annex 3. In summary it is observed that:

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

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

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

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

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

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

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

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

- responder beacons of various design,
- passive devices,
- DF identification using radar antennae,
- suggestions other than identification.

For further details on such types of devices, see Annex 3 to Doc. 71 (Warsaw).

5. Discussion of documents

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

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

6. Future work

It was generally agreed in the discussions that it would be most desirable for the C.C.I.R. to obtain from responsible shipping and administrative authorities, their views on the navigational requirements that should be met by radar identification devices. However, at the IXth Plenary Assembly, Los Angeles, 1959, the responsible authorities had not, in fact, advised the C.C.I.R. of any operational requirements for such devices and consequently the studies were terminated.

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REPORT 320-1

SELECTIVE-CALLING SYSTEMS FOR THE INTERNATIONAL MARITIME MOBILE SERVICES

(Question 3/XIII, Study Programme 3A/XIII)

(1963 – 1966)

1. Study Programme 3A/XIII states that Recommendation 257 does not give a full reply to Question 271 and the trials of selective calling systems, described in Docs. XIII/10, XIII/18, XIII/26 and 189, Los Angeles, 1959 were carried out with a view to coming to a decision on the type of system that should be adopted internationally.

The Administrations of the Federal Republic of Germany and the U.S.A. carried out comparative tests. Reference is made to Docs. 229 and 235, Geneva, 1963.

Study Group XIII studied the results of these tests during the session of the Xth Plenary Assembly, and took into consideration Docs. XIII/6, 8, 9, 11, 15, 19 and 21, Geneva, 1963.

The results of further tests carried out by several Administrations are given in the report of an International Working Party set up by the Xth Plenary Assembly (Doc. XIII/19, 1963-1966).

2. The Study Group has further studied the subject during the session of the XIth Plenary Assembly, on the basis of the work of the International Working Party on selective calling devices, and took into consideration further information contained in additional documents considered at the Interim Meeting of Study Group XIII, Geneva, 1965, listed in the Conclusions of that meeting, and documents submitted to the XIth Plenary Assembly, listed in the Chairman's Report (Doc. XIII/107, 1963-1966).

3. Study Group XIII has come to the conclusion that it is important that the operational and technical characteristics of a world-wide maritime selective calling system should be standardized as soon as possible.

No decision can be taken at present regarding the selective calling system to be adopted on a world-wide basis. The operational requirements should be defined more precisely and further tests including tests, under practical operating conditions, should be made.

Account should be taken of the fact that different national selective calling systems, already in operation on a limited scale, may expand in the absence of early international agreement and, for economic reasons, preclude international standardization.

To expedite agreement on a world-wide basis, the studies must be continued without delay and attention is drawn to Resolution 19-1.

4. The discussions during the Xth Plenary Assembly made it clear that all selective calling systems tested by the Administrations of the Federal Republic of Germany (Doc. 229) and the U.S.A. (Doc. 235) are capable of operating satisfactorily in the VHF band with class of emission F3.

They also indicated that it would be advantageous for the world-wide selective calling system to be suitable for operation in the radiotelephone maritime MF and HF bands, having regard to the probable additional requirement for SSB operation in accordance with Recommendation 258-1.

5. Discussions at the XIth Plenary Assembly showed the desirability for the system to be suitable for operation in both the maritime radiotelegraph and radiotelephone services. In addition, a different type of system was described in Doc. XIII/76 (U.S.A.).

6. After discussion, it was decided that operational requirements and technical characteristics should be defined more precisely and that further tests should be carried out and that for this purpose an International Working Party should again be set up (see Resolution 19–1).

7. The requirements of the further tests to be carried out may be summarized as follows:

7.1 as far as possible, the tests should be extended to include all classes of emission used in the maritime mobile services;

7.2 tests should also be carried out under practical operating conditions, including the effects of fading, interference and atmospherics, and the report should contain information with regard to:

7.2.1 reliability (ratio of calls received to calls transmitted), for high and low field strengths;

7.2.2 immunity against false calls (ratio of false calls received to calls transmitted), caused by such phenomena as speech modulation, intermodulation, etc. and interference from other selective calls;

7.2.3 an indication of the complexity of the different receiving selectors, such as number of tubes, transistors, relays and frequency-selective elements; also whether any components used are special or critical, especially as regards adjustment and maintenance;

7.2.4 an indication of the relative cost of typical equipment tested should, as far as possible, be given.

8. An indication of the patent situation should be included in the report by the International Working Party.

REPORT 359 *

USE OF A CONTROL TONE ** FOR AUTOMATIC GAIN CONTROL OF RECEIVERS IN SINGLE-SIDEBAND RADIOTELEPHONE SYSTEMS OPERATING IN THE HF MARITIME MOBILE BANDS

(1966)

In Question 282, the C.C.I.R. has been asked to consider what arrangements should be adopted in an A3J emission to control the gain of the receiver in the absence of speech. This problem was considered at the Interim Meeting of Study Group XIII, Geneva 1965 (see Docs. XIII/12 (United Kingdom), XIII/32 (Japan) and XIII/44 (Federal Republic of Germany), 1963-1966). The following conclusions have been reached:

1. For some Administrations, and for some types of ship equipment, it is essential that continous information should be available in SSB transmissions on which the gain (and in some cases frequency) of the receiving equipment can be automatically controlled, and in those cases the following arrangements should be adopted:

1.1 In the direction ship-shore this information should be in the form of a continuous signal at a level of approximately – 16 dB relative to peak envelope power.

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* This Report, which was adopted unanimously, can, together with Recommendation 258-1, be considered as an answer to Question 282, which is thereby terminated.

** The Study Group's interpretation of the Question is that the term " control tone " means " control signal ".

1.2 In the direction shore-ship the information should also be in the form of a continuous signal at a level of approximately – 16 dB relative to p.e.p.

1.3 In both directions the information should be emitted at a radio-frequency corresponding to the nominal carrier frequency.

REPORT 360 *

OPERATIONAL PROCEDURES FOR SINGLE-SIDEBAND (SSB) RADIOTELEPHONE SYSTEMS IN THE HF MARITIME MOBILE BANDS

(Question 4/XIII)

(1966)

Question 319 was adopted by correspondence after the Interim Meeting, Geneva, 1965, and was subsequently designated Question 4/XIII.

Since Question 319 was adopted, two documents have been submitted: Doc. XIII/73 (Senegal) and Doc. XIII/75 (U.S.A.), 1963-1966.

Doc. XIII/73 (Senegal) suggests that initial arrangements for radiotelephone calls at HF should be made by prior arrangement over a radiotelegraph channel. It is suggested that the ship also use initially a continuous identifying signal for the benefit of the coast station. A carrier 20 dB below peak envelope power is considered necessary. (Recommendation 258-1 recommends a carrier level of -16 ± 2 dB relative to p.e.p.). In the direction shore-ship similar procedures are proposed.

Doc. XIII/75 (U.S.A.) proposes that a carrier 16 dB below peak envelope power be continuously provided in both the ship-shore and shore-ship directions.

To assist the World Maritime Administrative Radio Conference, 1967, further study of Question 4/XIII is urgently required, and the possibility of the introduction of selective calling should be borne in mind.

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* This Report was adopted unanimously.

REPORT 361 *

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

(Question 5/XIII)

(1966)

1. Introduction

At the Interim Meeting of Study Group XIII, Geneva, 1965, the following papers were submitted and discussed: Doc. XIII/38 (Norway); Doc. XIII/45 (C.C.I.R. Secretariat) containing Doc. III/82 (Netherlands). This resulted in Question 5/XIII being formulated and adopted by correspondence.

The following additional documents were submitted to the XIth Plenary Assembly (Oslo): Docs. XIII/73 (Senegal); XIII/82 (U.K.); XIII/93 and XIII/94 (Canada); XIII/105, XIII/106, XIII/119 (Netherlands); XIII/113, XIII/114 (Federal Republic of Germany); XIII/120 (Norway), 1963-1966. Reference should also be made to Report 349.

1.1 *Doc. XIII/73 (Senegal)* proposes that the direct-printing system should be an error indicating type, that the maximum modulation rate should be 50 bauds, that the radio circuit should use class of emission F1 and that the quality of transmission should be 1 error per 10 000 characters.

1.2 *Doc. XIII/82 (United Kingdom)* describes an automatic one-way error-correcting system used for ship-shore and shore-ship transmission of messages, data and press. The system accepts start-stop signals which conform to C.C.I.T.T. standards and produces similar signals at the receiver output.

The ten-unit code used for transmission consists of the 5 elements of the International Teleprinter Code No. 2 followed by 5 parity check elements. The 5 parity elements are either an erect or an inverse repetition of the information elements, depending on whether the *Z* count in the information elements is odd or even. This system is capable of correcting all single element errors in the characters in the text and of detecting all double element errors as well as most multiple element errors introduced by the transmission path. Errors which are detected, but cannot be corrected, are indicated by the printing of "error" symbols, usually combination 31 or 32. A synchronous mode of transmission is employed. The modulation rate is then 62·3, 68·5 or 102 bauds for teleprinter circuits operating at modulation rates of 45·45, 50 and 75 bauds respectively. At the lower modulation rates the system is capable of extension over the public telegraph network using conventional 50-baud circuits.

No special phasing signals are required as the system is capable of fully automatic phasing during periods of traffic as well as during periods of idling.

The system reported in Doc. XIII/82 is currently in commercial service. Over the period 7 August 1965 to 27 November 1965 a total number of 1099 data tapes, each containing between 1500 and 1800 characters, were transmitted from ships at sea to an office in London, Of these, 889 were accepted without need for later re-transmission (i.e. contained no errors).

It is further reported that tests between ship and shore stations with plain language messages, and ship-borne reception of broadcast services (e.g. press transmission) were considered satisfactory, provided some measure of diversity reception is used.

* This Report was adopted unanimously.

1.3 *Doc. XIII/93 (Canada)* proposes an addition to the considerings of Question 320 (XIII).

1.4 *Doc. XIII/94 (Canada)* proposes specific families of tones for mark and space (including provision for frequency diversity). A unidirectional system with an error indicating and correcting 10-unit code is preferred to an ARQ system. An average error-rate of 1 in 1000 characters at the C.C.I.T.T. preferred standard of 50 bauds is proposed. Suggestions for operational procedures are given.

1.5 *Doc. XIII/45 (Netherlands)* describes a single-channel simplex ARQ system according to Report 348 which is used for ship-shore communication to pass messages, data and press.

It accepts signals in any 5-unit code and produces similar start/stop signals at the receiver output at a modulation rate of 50 bauds, and a 150 ms character cycle. The code used for transmission consists of seven elements per character with a constant A to Z ratio. This code is used for error detection. All detected errors are automatically corrected by means of ARQ.

A synchronous mode of transmission is employed at a modulation rate of 100 bauds.

The system provides automatic, error-free phasing, within one second. In addition, the phasing signals are used to provide selective calling facilities. The system provides for rapid reversal of traffic flow thus enabling the user of this system to participate in the telex network.

The system is capable of using one frequency for both the transmission paths. It is in commercial service and has been for about 4 years.

1.6 *Doc. XIII/105 (Netherlands)* is a report on a one-way system for message broadcasting with error-correcting and indicating facilities. The system accepts and produces at the receiver the 5-unit start-stop International Telegraph Alphabet No. 2, at a modulation rate of 50 bauds. For radio transmission, the start-stop code is converted into a synchronous, 7-unit code at a modulation rate of 100 bauds. Each character is transmitted twice with an interval of 350 ms, thus giving a time diversity effect. At the receiving terminal, the first character is checked for correct 3/4 ratio of A/Z elements, and if correct, is fed to a delay storage circuit. If the character is mutilated, the second transmission is examined, and if correct, is printed. If both transmissions are mutilated, then a space symbol is sent to the teleprinter. Before starting the transmission of information and in the idle time between successive messages or message blocks, the transmitting station emits idle time signals which are also used for phasing. Equipment designed for a 3-character ARQ system (see Docs. XIII/45 or III/82, 1963-1966) has been modified to include the new unidirectional transmission system. Its performance when tested in the laboratory, under conditions simulating various types of fading, is shown in Report 349.

1.7 *Doc. XIII/106 (Netherlands)* contains proposed answers to Question 5/XIII, based on Docs. XIII/45 and XIII/107, 1963-1966. In particular, it is proposed that the system should be suitable for communication between ships and one coast station, and from one coast station to a number of ships; the modulation rate should be about 100 bauds; the class of emission F1, with a shift between 85 and 400 Hz or class of emission A3J, and the average efficiency should be between 70% and 100%.

1.8 *Doc. XIII/119 (Netherlands)* tabulates the results of ship-shore and shore-ship tests with a simplex-ARQ system described in § 1.5 Details of the equipment used are given. The undetected error-rate was better than 1×10^{-5}. The mean efficiency factor was generally of the order of 80%. These figures indicate that the undetected error-rate is better than that obtained with conventional ARQ systems used in the fixed service.

1.9 *Doc. XIII/113 (Federal Republic of Germany)* observes that. when duplex operation is possible, a conventional ARQ system on a single channel basis as described in Report 350 is preferred.

1.10 *Doc. XIII/114 (Federal Republic of Germany)* expands on Doc. XIII/113 as far as duplex and simplex operations are concerned; it concludes that the ARQ method is preferred to forward error correction. It also concludes that transmission quality is improved if the modulation rate is not more than 100 bauds and that class of emission F1 is preferable. It is suggested that the efficiency factor should not fall below 70-80%.

1.11 *Doc. XIII/120 (Norway)* describes tests between ship and shore and shore and ship, using the two systems described in Docs. XIII/82 (U.K.) and XIII/45 (Netherlands) 1963-1966. The equipment used is listed. The results are tabulated. For the forward error-correcting system, the undetected error-rate was of the order of $3–5 \times 10^{-4}$. For the ARQ system the average error rate is approximately $2{\cdot}6 \times 10^{-5}$ and the average efficiency 75-77%. The tests with both systems are being continued.

2. Conclusions

Whilst the information so far available does not permit a complete answer to Question 5/XIII, the following interim conclusions may be reached:

2.1 Tests of the systems tried even at this stage show that direct telegraph printing is feasible in the maritime mobile service for messages, data and news, and for interconnection with the public telegraph network (See I.T.U. List of Definitions, Part I, Item 01.12.). However, more operational experience is required for defining the type of system to be used in the maritime mobile service, and the standards to be attained, taking into account economic factors.

2.2 The systems so far described and tested do not require a higher modulation rate than 100 bauds.

D. 3: Land mobile service

REPORT 319-1 *

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS BETWEEN 25 AND 500 MHz FOR LAND MOBILE SERVICES

(Question 7/XIII)

(1963 - 1966)

1. The following documents have been submitted in reply to Question 163 (subsequently designated Question 7/XIII):

1.1 *To the IXth Plenary Assembly, 1959:*
XIII/4 (New Zealand), XIII/2 and XIII/11 (F.R. of Germany), XIII/30 (Japan), XIII/32 (United Kingdom), 180 (Sweden).

1.2 *To the Xth Plenary Assembly, 1963:*
XIII/1 (F.S.R. of Yugoslavia), XIII/4 (Greece), XIII/10 and 259 (P.R. of Poland), XIII/24 (F.R. of Germany), 222 (Australia).

1.3 *To the XIth Plenary Assembly, 1966:*
XIII/24 (United Kingdom), XIII/29 (Japan), XIII/33 (P.R. of Poland), XIII/39 (Rev. 1) and XIII/83 (F.R. of Germany), XIII/86 (Denmark), XIII/96 (Switzerland), XIII/110 and XIII/111 (Japan), XIII/116 (France), XIII/121 (New Zealand), XIII/123 (U.S.A.).

2. The technical information contained in these documents, together with other information submitted direct during the Plenary Assemblies are given in the Annex to this Report. The data arranged according to the separation between adjacent channels adopted in the various countries are given in Table III. Tables I and II give these separations, the names of countries being replaced by the symbols used for them in Table I of the Preface to the International Frequency List.

It would be desirable for frequency tolerances and spurious emission levels to be expressed in absolute values in future.

The information given in this Annex shows that it is difficult at present to reach complete international standardization of the performance characteristics of land mobile equipment operating between 25 and 500 MHz. However, it is desirable that countries with common borders should reach agreement on some common characteristics, which would be helpful in planning for the land mobile services.

3. *Doc. XIII/24 (United Kingdom)* lists characteristics of transmitters and receivers which are significant in causing interference and proposes methods of measuring these characteristics. Administrations are invited to furnish similar information with a view to reaching international agreement on methods of measurement. This could then lead to a revision of the data in the Annex on a uniform basis, preparatory to consideration by the C.C.I.R. of the limits to be specified for such characteristics.

At a later stage similar consideration could be given to those characteristics of receivers that give protection against interference.

4. *Doc. XIII/39 (Rev. 1) (F.R. of Germany)* deals with processes used for the assignment and co-ordination of frequencies.

Some special information concerning the co-ordination of frequencies on a multilateral basis is given in the " Special Agreement between the Administrations of Belgium, the Netherlands and the F.R. of Germany relating to the use of metric and decimetric waves for fixed and mobile services in border areas, Brussels, 1963 ".

Docs. XIII/80 (United Kingdom) and XIII/111 (Japan) deal with certain characteristics of land mobile stations and frequency usage which affect frequency co-ordination methods.

* This Report, which replaces Report 319, was adopted unanimously.

Administrations are invited to examine and amplify the ideas set out in these documents.

5. Some information concerning interference between mobile services and broadcasting services is given in the Final Acts of the Special Regional Conference, Geneva, 1960.

6. Resolution 20-1 invites Administrations to continue to send to the C.C.I.R. for circulation details of performance specifications and measuring methods and also to send details of practices for the allocation of channels between 25 and 500 MHz to the land mobile services in operation in their respective countries.

7. The study of Question 7/XIII should be continued.

ANNEX

1. *Adjacent-channel separation in the various frequency bands*

TABLE I

Separations now in use but considered out of date

Channel Separation (kHz)	Frequency ranges (MHz)			
	25–50	50–100	100–200	200–500
10				
12·5				
15				
20				
25	NZL(1)	NZL(1)	NZL(1)	
30		J–		
40			J–	
50	BEL–DNK–F–POL–S(3)–SUI	BEL–D–DNK–F–NOR–NZL(1)–S(2)–SUI	BEL–D–DNK–NOR–NZL(1)–POL–S(3)–SUI	J–SUI–USA
66				
100	D–NOR–SUI			

(1) An interleaved channel allocation plan is used and only alternate channels are allocated in any one geographical area. Consequently, the equipment is designed for double the channel separation shown above.

(2) No new assignments have been made since 1959. Old stations are permitted to stay until 1970.

(3) No new assignments have been made since 1960. Old stations are permitted to stay until 1971.

TABLE II

Separations for present and/or future use.

Channel separation (kHz)	Frequency ranges (MHz)			
	25–50(1)	50–100(1)	100–200	200–500
6·25	NZL(2)	NZL(2)	NZL(2)	
10	D *–DNK–DNK *–NOR *–S *–SUI *–USA			NZL(2)
12·5				
15		J	USA(2)	
20	D–USA	D–BEL(3)	BEL(3)–D–F–J	BEL(3)–D
25	DNK–F–NOR–POL–S(5)–SUI	BEL(3)–DNK–F–NOR–S(4)–S(4) *–SUI	BEL(3)–DNK–NOR–POL–S(5)–SUI	BEL(3)–J–NOR–SUI–USA
30			USA	
40	USA *			
50	BEL			BEL(3)–DNK–F–NOR–POL–S(6)
66				
100				

(1) When a country symbol is followed by an asterisk, the value given for the separation refers to low-power portable equipment.
(2) An interleaved channel allocation plan is to be used and only alternate channels allocated in any one geographical area. Consequently the equipment is designed for double the separation shown above.
(3) The choice between the separation 20, 25 and 50 kHz is still under study.
(4) In use since 1959.
(5) In use since 1960.
(6) In use since 1965.

2. Technical characteristics of equipment

TABLE III (8) (9)

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Receiver: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
10	25–50	D	(O)	Private	0	0·1(m)	A3 F3		7 7	1·5 kHz 1·5 kHz	4 × 10^{-3} µW in bands: 47–68 MHz 174–230 470–790 In all other bands 10 µW						2 × 10^{-3}	
		DNK	XIII/86 (O)	Private	0	0·1(M)	A3		6	1·5 kHz	4 × 10^{-3} µW in bands: 47–68 MHz 174–230, 470–790 In all other bands: 10 uW						4 × 10^{-3}	In frequency band 27·12 MHz ±0·6% only
						Max: 5 input (B, M)	A3		6	3 kHz	Input up to 1 W: −40 dB Input up to 5 W: −50 dB						0·01	In frequency band 29·7–31·7 MHz only
		NOR	(O)	Private	0	0·5	A3		6	1·5 kHz	RR						RR	
		S	(O)	Private	0	0·5 (mMB) 5 (mMB)	A3		6	50 × 10^{-6}	20 µW −40 dB } (H) 0·2 µW −60 dB } (NH)	Super-regenerative receivers not permitted						In frequency band 26–30 MHz
		SUI	(O)	Private	0	0·5 (m)			40*	5 kHz	8 µW						0·02 (H) 2 × 10^{-3} (NH)	* between −40 dB points
15	50–100	J	(O)	Public and Private	2 4·5	50	F3	5	16	0·6 kHz	−80dB (IB) −60dB (OB)	2	20	−70 at 12·5 kHz	0·6 kHz	−80	4 × 10^{-3}	(2S) (IB) = in band (OB) = out band

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Receiver: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (μV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (μW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
	100–200	USA	XIII/123 (O)															The 15 kHz separation is occasionally permitted but with the same equipment characteristic as for the 30 kHz separation
20	25–50	USA	XIII/123 (O)	Private and Public	0·5–8	330 (B) 100 (M)	F3	5	20	20 × 10^{-6}	50 μW	[0·6]	12 *	[−80 at 20 kHz]**	[20 × 10^{-6}]	−100		* $\frac{S+N+D}{N+D}$ ** 2-signal test with 6 dB degradation of 12 dB $\frac{S+N+D}{N+D}$
	50–100	D	XIII/83 (O)	Private	9·8	1 6	F3	4	14	1·2 kHz	20 μW (H) 0·2 μW (NH)	[2]	20	−70 at 20 kHz	1·2 kHz	−70	2 × 10^{-3}	
	100–200	D	XIII/24 G	Private	4·6	1 6	F3	4	14	1·6 kHz (M) 0·8 kHz (B) 1·8 kHz (m)	20 μW (H) 0·2 μW (NH)	[2]	20	−70 at 20 kHz	1·6 kHz (M) 0·8 kHz (B) 1·8 kHz (m)	−70	2 × 10^{-3}	
		F	XIII/116 (O)	Public and Private	4·6	30 (M) 50 (B)	F3	4	14	1·6 kHz (M) 0·8 kHz (B)	RR	2	20	−80 at 20 kHz		−60		
		J	(O)	Public and Private	2 4·5	50	F3	5	16	1·5 kHz	−80 dB (IB) −60 dB (OB)	2	20	−70 at 12·5 kHz	1·5 kHz	−80	4 × 10^{-3}	(2S) (IB) = in-band (OB) = out-band
	200–500	D	XIII/83 (O)	Private	10	1 6	F3	4	14	2·5 kHz (mM) 1·0 kHz (B)	20 μW (H) 0·2 μW (NH)	[3]	20	−70 at 20 kHz	2·5 kHz (mM) 1·0 kHz (B)	−70	2 × 10^{-3}	
25	25–50	AUS	222 (G)	Private		25 (M) 50 (B)	A3 and F3	5	6 or 16	20 × 10^{-6}	Less than 2·5 μW at 50 kHz from carrier	11	10	−80 at 25 kHz		−80 to 25 kHz		

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
		DNK	XIII/86 (O)	Private	0·6–5	25	A3 or F3	5	6 or 16	3 kHz (M) 1·5 kHz (B)	2.5 µW			−70 at 25 kHz		−75 at 25 kHz	0·01	(2S)
		F	XIII/116 (O)	Private	4·4	30 (M) 50 (B)	F3	5	16	0·8 kHz	RR	2	20	−80 at 25 kHz		−60		
		NOR	(O)	Private	5–10	25 (M) 100 (B)	A3 or F3	5	6 16	1 kHz	2·5 µW (H) 0·25 µW (NH)	1·5	10	−70 at 22 kHz	1 kHz		0·02	
		S	(O)	Private	0	40 (M) 70 (B)	A3 and F3	5	16	20×10^{-6} (M) 10×10^{-6} (B)	20 µW −40 dB (H) 0·2 µW −60 dB (NH)			−80 at 25 kHz	20×10^{-6} (M) 10×10^{-6} (B)	−70	0·01	(2S)
25	50–100	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6}	Less than 2·5 µW at 50 kHz from the carrier	1	10	−80 at 25 kHz		−80 at 25 kHz		
		DNK	XIII/86 (O)	Private	0·6–5	25	A3 or F3	5	6 or 16	3 kHz (M) 1·5 kHz (B)	2·5 µW			−70 at 25 kHz		−75 at 25 kHz	0·01	(2S)
		F	XIII/116 (O)	Private	4·05–5	30 (M) 50 (B)	F3	5	16	1·6 kHz	RR	2	20	−80 at 25 kHz		−60		
		G	XIII/32 (L.A.)	Private	4·8 to 13·5	25 (e.r.p.)	A3 or F3	5	6 or 16	3·0 KHz (M) 1·5 kHz (B)	2·5 µW	5	10	−70 at 25 kHz	3.0 kHz (M) 1·5 kHz (B)	−70		(2S)
		NOR	(O)	Public and Private	5–10	25 (M) 100 (B)	A3 or F3	5	6 16	1·5 kHz	2·5 µW (H) 0·25 µW (NH)	1·5	10	−70 at 22 kHz	1·5 kHz	−70	0·02	
		NZL	(O)	Public and private	4	25	A3		6	3 kHz (M) 1·5 kHz (B)	2·5 µW	2·5	10	−70 at 25 kHz	3 kHz (M) 1·5 kHz (B)	−70	0·02	(2S)

						Transmitter						Receiver						
Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Typical mean power (2) (W)	Class of emission	Max. deviation (kHz)	Occupied bandwidth (5) (kHz)	Frequency tolerance ± (2)	Spurious emissions (3) (4)	Sensitivity (e.m.f.) (μV)	Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Selectivity (dB)	Frequency tolerance ± (2)	Spurious responses (dB)	Spurious radiations (μW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
		S	180 (L.A.) (O)	Public and private	0 0·6 4·8 5·0	40 (M) 70 (B)	F3 and A3	5	16	20×10^{-6} (M) 10×10^{-6} (B)	20 μW −40 dB (H) 0·2 μW −60 dB (NH)			−80 at 25 kHz	20×10^{-6} (M) 10×10^{-6} (B)	−70	0·01	(2S)
		SUI	XIII/96 (O)	Public	10	20 (M) 50 (B)	A3 or F3			1·5 kHz	8 μW (H) 2 μW (NH)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}	(2S)
				Private		10 (M) 20 (B)		4·5	20	2 kHz		no specifications					2×10^{-3}	
	100–200	DNK	XIII/86 (O)	Public and private	4–9	25	A3 or F3	5	6 or 16	3 kHz (M) 2·5 kHz (B)	2·5 μW			−70 at 25 kHz		−75 to 25 kHz	0·01	(2S)
		G	XIII/32 (L.A.)	Private	4·8 to 13·5	25 (e.r.p.)	A3 or F3	5	6 or 16	3·0 kHz (M) 1·5 kHz (B)	2·5 μW	5	10	−70 at 25 kHz	3·0 kHz (M) 1·5 kHz (B)	−70		(2S)
		NOR	(O)	Public and private	4·5 8	25 (M) 100 (B)	A3 or F3	5	6 or 16	3·0 kHz (M) 1·0 kHz (B)	2·5 μW (H) 0·25 μW (NH)	1·5	10	−70 at 22 kHz	3·0 kHz (M) 1·0 kHz (B)	−70	0·02	
		NZL	(O)	Public and private	4 and 2	25	A3 or F3	5	6 or 16	2 kHz (M) 1 kHz (B)	2·5 μW	2·5	10	−70 at 25 kHz	2 kHz (M) 1 kHz (B)	−70	0·02	(2S)
		S	(O)	Public and Private	0 and 8	40 (M) 70 (B)	F3 and A3	5	16	10×10^{-6} (M) 5×10^{-6} (B)	20 μW −40 dB (H) 0·2 μW −60 dB (NH)			−80 at 25 kHz	10×10^{-6} (M) 5×10^{-6} (B)	−70	0·01	(2S) In the band 100–103·5 MHz the values given in column 7 must be replaced by "3" and in columns 11 and 15 by: 20×10^{-6} (M) 10×10^{-6} (B)
		SUI	XIII/96 (O)	Public	10 *	20 (M) 50 (B)	A3 or F3			1·5 kHz	8 μW (H) 2 μW (NH)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}	* A separation of 4·6 MHz is planned
				Private		10 (M) 20 (B)		4·5	20	2 kHz		no specifications					2×10^{-3}	(2S)

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
	200–500	J	(O)	Public		4 (M) 100 (B)	F3	5	16	0·9 kHz (B) 2·3 kHz (M)	−60 dB	1·6	20	−70 at 15 kHz	0·9 kHz (B) 2·3 kHz (M)	−80	4×10^{-3}	(2S)
			XIII/111 (O)	Private		50	F3	5	16	2·3 kHz	−60 dB	2·5	20	−70 at 15 kHz	2·3 kHz	−80	4×10^{-3}	
		SUI	(O)	Public	10	20 (M) 50 (B)	A3 or F3	4·5	20	1·5 kHz	8 µW (H) 2 µW (NH)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}	(2S)
				Private		10 (M) 20 (M)				2 kHz		no specifications					2×10^{-3}	
30	50–100	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6}	Less than 2·5 µW at 50 kHz from carrier	1·5	10	−76 at 30 kHz		−76 at 30 MHz		
		J	XIII/30 (L.A.) (O)	Public and Private	2–4·5	50	F3	10	26	1·2 kHz	−80 dB (IB) −60 dB (OB)	2	20	−70 at 25 kHz	1·2 kHz	−80	4×10^{-3}	(2S) (IB) = in-band, (OB)= out-band
	100–200	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6} (M) 10×10^{-6} (B)	Less than 2·5 µW at 60 kHz from carrier	2·5	10	−72 at 26 kHz		−72 at 26 kHz		
		USA	XIII/123 (O)	Public and Private	0·5–5·26	330 (B) 100 (M)	F3	5	20	5×10^{-6}	50 µW	0·8	12 *	[−80 at 30 kHz]	[5×10^{-6}]	[−95]		* $\frac{S+N+D}{N+D}$ ** 2-signal test with 6 dB degradation of 12 dB $\frac{S+N+D}{N+D}$
40	100–200	J	XIII/30 (L.A.) (O)	Public and Private	2–4·5	50	F3	12	30	2 kHz	−80 dB (IB) −60 dB (OB)	2	20	−70 at 25 kHz	3 kHz	−80	4×10^{-3}	(2S) (IB) = in-band (OB) = out-band

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (uV)	Receiver: Sensitivity, for a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
50	25–50	F	XIII/116 (O)	Private	4·4	30 (M) 50 (B)	F3	15	36	2 kHz	RR	2	20	−80 at 50 kHz		−60		
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		20 (M) 50 (B)	F3	15	42	2 kHz	25 µW (M) −60 dB (B)	2	20	−70 at 50 kHz	2 kHz	−60		Receiver selectivity and spurious responses with 2–signal test
		S	180 (L.A.) (O)	Private	0	25 (M) 50 (B)	F3 and A3	15	36	100×10^{-6}	−40 dB (M) −60 dB (BM)							(2S)
	50–100	NZL	(O)	Public and Private	4	25	A3		6	5 kHz (M) 1·5 kHz (B)	2·5 µW	2·5	10	−70 at 50 kHz	5 kHz (M) 1·5 kHz (B)	−70	0·02	(2S)
		S	180 (L.A.) (O)	Public and Private	0	25 (M) 50 (B)	F3 and A3	15	36	100×10^{-6}	−40 dB (M) −60 dB (MB)							(2S)
		SUI	XIII/96 (O)	Public	10	20 (M) 50 (B)	A3 or F3			3 kHz	8 µW (H) 2 µW (NH)	1	20	−60 at 40 kHz	2 kHz		2×10^{-4}	(2S)
				Private		10 (M) 20 (B)		15	40	5 kHz		no specifications					2×10^{-3}	
	100–200	D	XIII/83 (O)	Public	4·5	10 (M) 20 (B)	F3	15	36	2·5 kHz	20 µW (H) 0·2 µW (NH)	2	20	−70 at 50 kHz	2·5 kHz	−70	2×10^{-3}	
		G	XIII/56 (O)	Public	4·5	25 (M) 100 (B)	F3	15	36	3 kHz (M) 2 kHz (B)	2·5 µW	2	20	−70 at 50 kHz	3 kHz (M) 2 kHz (B)			(2S)
		NZL	(O)	Public and Private	4	25	A3 or F3		6 or 16	5 kHz (M) 1·5 kHz (B)	2·5 µW	2·5	10	−70 at 50 kHz	5 kHz (M) 1·5 kHz (B)	−70	0·02	(2S)
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		20 (M) 50 (B)	F3	15	42	3 kHz	25 µW (M) −60 dB (B)	2	20	−70 at 50 kHz	3 kHz	−60		Receiver selectivity and spurious responses with 2–signal test

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Receiver: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
		S	180 (L.A.) (O)	Public and Private	0 and 8	25 (M) 50 (B)	F3 and A3	15	36	100 × 10^{-6}	−40 dB (M) −60 dB (MB)							(2S) In the band 100–103·5 MHz the values given in column 7 must be replaced by: "3"
		SUI	XIII/96 (O)	Public	10 *	20 (M) 50 (B)	A3 or			3 kHz	8 µW (H) 2 µW (NH)	1	20	−60 at 40	2 kHz		2 × 10^{-4}	* A separation of 4·6 MHz is planned
				Private		10 (M) 20 (B)	F3	15	40	5 kHz		no specifications					2 × 10^{-3}	(2S)
	200–500	DNK	XIII/86 (O)	Private	8–15	250	A3 or F3	15	6 or 36	5 kHz (M) 3·5 kHz (B)	25 µW			−70 at 50 kHz		−75 at 50 kHz	0·01	(2S)
		F	XIII/116 (O)	Private	12·5		F3	15	36	5·6 KHz (M) 3·3 kHz (B)	*	2	20	−80 at 50 kHz		−60		* Same tolerance as RR for the 30–235 MHz band
		G	XIII/56 (O)	Private	5·5 to 6·5	50 (e.r.p.)	A3 or F3	15	6 or 16	5 kHz (M) 3·5 kHz (B)	25 µW	10	10	−60 at 50 kHz	5 kHz (M) 3·5 kHz (B)	−60		(2S)
		J	XIII/29 (O)	Public and Private		50	F3	12	30	9·4 kHz	−60 dB	2·5	20	−70 at 30 kHz	9·4 kHz	−80	4 × 10^{-3}	Single signal selectivity. See also Notes (6) and (7)
		NOR	(O)	Private	5	15 (M) 50 (B)	F3	15	36	5 kHz (M) 3 kHz (B)	2·5 µW	1·5	10	−70 at 50 kHz	5 kHz (M) 3 kHz (B)	−70	0·02	
		NZL	(O)	Public and Private	10	50	A3 or F3	15	6 or 36	5 kHz (M) 2·5 kHz (B)	2·5 µW	2·5	10	−70 at 50 kHz	5 kHz (M) 2·5 kHz (B)	−70	0·02	(2S)

Channel Separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation (kHz)	Transmitter: Occupied bandwidth (5) (kHz)	Transmitter: Frequency tolerance ± (2)	Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Remarks (10)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		15 (M) 50 (B)	F3	12	30	3 kHz	25 µW (M) −60 dB (B)	2·5	20	−70 at 50 kHz	3 kHz	−60		Receiver selectivity and spurious responses with 2–signal test
		S	(O)	Private	0 7 10 15 21 30	15	F3	15	36	10 × 10⁻⁶ (M) 5 × 10⁻⁶ (B)	20 µW, −40 dB } (H) 0·2 µW, −60 dB } (NH)			−70 at 50 kHz		−70	0·01	(2S)
		SUI	XIII/96 (O)	Public	10	20 (M) 50 (B)	A3 or F3			3 kHz	8 µW (H) 2 µW (NH)	1	20	−60 at 40 kHz	2 kHz		2 × 10⁻⁴	(2S)
				Private		10 (M) 20 (B)		15	40	5 kHz		no specifications					2 × 10⁻³	
		USA	XIII/123 (O)	Public and Private	5	250 (B) 50 (M)	F3	15	40	5 × 10⁻⁶	50 µW	[1,4]	12 *	[−70 at 50 kHz] **	[5 × 10⁻⁶]	[−90]		* $\frac{S+N+D}{N+D}$ ** 2–signal test with 6 dB degradation of 12 dB $\frac{S+N+D}{N+D}$
66	100–200	GRC	XIII/4 (G)	Private		20 (M) 50 (B)	F3	15	36	3 kHz	−70 dB	0·5 1	12 (M) 12 (B)	−86 at 60 kHz	3 kHz	−70		
100	25-50	YUG	XIII/1 (G)	Private		20	F3	15	36	15×10⁻⁶	−30 dB	1	10	−80 at 100 kHz	50 × 10⁻⁶			

(1) L.A. = Los Angeles, 1959; G = Geneva, 1963; O = Oslo, 1966.
(2) B = base station; M = mobile vehicle station; m = mobile portable station.
(3) H = on harmonic frequencies; NH = on frequencies other than harmonics.
(4) RR = Radio Regulations, Geneva (1959).
(5) In some cases, the bandwidth is specified at the 20 dB points.
(6) Under the condition of injecting the desired frequency signal which is 6 dB higher than the 20 dB noise quieting level, the undesired frequency signal in the adjacent channel that is injected to the receiver and makes again 20 dB noise quieting, shall be above 80 dB (1 µV = 0 dB).

(7) In the absence of the desired signal and when the undesired signals of the adjacent and next adjacent channel frequencies are injected to the receiver at a level of 65 dB (1 µV = 0 dB), the noise quieting of the receiver shall be less than 20 dB.
(8) It would be desirable for data relating to a new column " Intermodulation " to be supplied by Administrations; this new column would be inserted between the present columns 17 and 18.
(9) The values given in square brackets [. . .] are considered optional by the Administrations which have supplied them.
(10) (2S) = receiver selectivity with 2-signal test.

D. 4: Aeronautical mobile service

No Reports in this Sub-section.

STUDY GROUP XIII

(Mobile services)

Terms of reference:

To study technical and operating questions concerning the aeronautical, maritime, land mobile, radiolocation and radionavigation services (except services that involve the use of earth satellites which, at present, are the concern of Study Group IV).

Chairman: Mr. G. H. M. Gleadle (United Kingdom)
Vice-Chairman: Mr. J. Søberg (Norway)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP XIII

1. **Opinion 20 and Report 317:** Codes and abbreviations for the International Telecommunication Services.

Opinion 20 asked Administrations to consider whether there was an operational need for the unification of the codes used in the international telecommunication services. No Administration, in fact, expressed a need for such unification and therefore it has been agreed in Recommendation (437) that no further action should be taken concerning the unification of codes. Report 317 has now been deleted.

2. **Resolution 19, Question 271 (XIII), Study Programme 271A (XIII), Report 320, Recommendation 257:** Selective calling devices for use in the international maritime mobile radiotelephone services.

At the Interim Meeting, Geneva, 1965, a draft Recommendation was prepared for a selective-calling system employing the principle of sequential single frequencies (s.s.f.c.) so that each digit of the code number of a ship was represented by a single frequency. This system had been tested extensively by the International Working Party. However, subsequent to the Interim Meeting, a different kind of system, a digital system, was proposed by the United States of America. In addition, further discussions at the XIth Plenary Assembly showed that there would probably be a need in the future for selective calling in other maritime services in addition to the radiotelephone service; for example, in conjunction with direct-printing radiotelegraph systems or radioteleprinter systems. It was also felt that the selective calling system should also provide an indication of the coast station that had called and/or the channel on which the ship should reply. It was finally decided that the International Working Party should be set up again (Resolution 19-1) to attempt to define more precisely the operational requirements and to supervise comparison tests of the new digital system and the s.s.f.c. system. The Question and Study Programme were amended accordingly (see Question 3/XIII and Study Programme 3A/XIII) and the Report was brought up to date (See Report 320-1). The Netherlands Administration again undertook to act as Chairman of the International Working Party and to carry out tests. The International Working Party has been asked to prepare a progress report by 1 April 1967 for discussion at an Interim Meeting in 1967, so that as much information as possible on this subject will be available in time for the Maritime World Administrative Radio Conference, September 1967.

Recommendation 257 was left unchanged for the time being.

3. **Question 163 (XIII), Resolution 20, Report 319:** Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UFH (decimetric) land mobile services.

3.1 The Question has been replaced by Question 7/XIII to extend the frequency range downwards to 25 MHz, so as to cover, *inter alia*, small portable equipment operating at frequencies in the neighbourhood of 27 MHz.

3.2 The Resolution has been replaced by Resolution 20-1 which now includes, in § 3, a reference to the relevant measuring methods, to facilitate a better understanding of the technical specifications in use by various Administrations.

3.3 The main Table of the Report (Report 319-1) has been considerably enlarged and brought up to date by the addition of fresh data from various Administrations. The main Table (Table III) has been rearranged so that the data is tabulated according to the separation between adjacent channels adopted by Administrations. Two other Tables, I and II, have been added to show the channel separations (I) now in use but out of date, and (II) separations for present and future use. Administrations are invited to furnish information to enable the tables to be completed.

3.4 Administrations have also been invited to furnish information on their specifications that appertain to the characteristics of transmitters and receivers that cause interference and on the methods of measurement of such characteristics. At a later stage the characteristics of receivers that give protection from interference could be considered. It was hoped that agreement on methods of measurement would lead eventually to a uniform presentation of the data on specifications in the new Table III.

3.5 The lattice-plan principle for the co-ordination of frequency assignments for land mobile services was also discussed. Although it was attractive for planning broadcast services where uniform coverage of an area was desired, some Administrations were doubtful whether the principle would be helpful in planning land-mobile services where the transmitting stations were often crowded together in large cities or industrial areas. Further study of the principles of planning mobile services and frequency usage would be desirable.

3.6 Three new Study Programmes deriving from Question 7 (XIII) were adopted, namely:

Study Programme 7B/XIII: Minimum channel separation and optimum modulation systems for land mobile systems between 25 and 500 MHz.

Study Programme 7A/XIII: Technical characteristics of land mobile equipment between 25 and 500 MHz.

Study Programme 7C/XIII: Interference due to intermodulation products in the land mobile services between 25 and 500 MHz.

3.7 A new Question 8/XIII was adopted, concerning the preferred technical characteristics of single-sideband equipment for the MF and HF land mobile services. This question is of particular concern to those administrations where land mobile services have to operate over much greater areas than can be covered by VHF and UHF services.

4. **Question (206 XIII) and Recommendation 428:** Direction-finding by ships in the 2 MHz band.

The Question was replaced by Question 2/XIII, particularly for further study of minimum technical measures for “ homing ”. The Recommendation was improved by the addition of new §§ 1.4, 1.5 and 1.7 containing fresh information.

5. **Opinion 21:** Emergency position-indicating radio beacons.

Question 318 was adopted by correspondence after the Interim Meeting, Geneva 1965, after considering the replies from I.C.A.O. and I.M.C.O. to the questions addressed to them in Opinion 21.

Recommendation 439, concerning beacons for operation on 2182 kHz, has been approved; and in view of the action already taken by Fourth Air Navigation Conference of I.C.A.O., a new Opinion (25), has been addressed to I.C.A.O. asking whether I.C.A.O. wishes the C.C.I.R. to consider beacons operating at 121.5 and 243 MHz.

Opinion 25 and Recommendation 439 terminate the study of Question 318.

6. **Question 272 (XIII):** Signal-to-interference protection ratios and minimum field-strengths required in the mobile services.

6.1 Recommendation 441 has been approved to give recognition to the provisions contained in the Convention of International Civil Aviation, Annex 10, Chapter 4, concerning the planning and protection of Aeronautical Mobile (R) Service frequencies above 30 MHz.

6.2 A preliminary Report 358 has been prepared concerning the VHF and UHF maritime and land mobile services and the HF maritime mobile service. Considerable additional data is required to determine appropriate protection ratios and values of field strength to be protected for these services.

7. **Question 273 (XIII):** Use of classes of emission A2H and A3H at the distress frequencies 500 kHz and 2182 kHz, respectively.

Recommendation 438 has been approved. At 500 kHz, class of emission A2H is considered as effective as class of emission A2 for alarm, distress, urgency and safety signals; and on 2182 kHz, class of emission A3H is considered as effective as class of emission A3. The new Recommendation terminates the study of Question 273 and doubtless the Recommendation will be taken into account at the Maritime World Administrative Radio Conference, 1967.

8. **Question 274 (XIII):** Facsimile transmission of meteorological charts for reception on board ships.

Opinion 24 has been addressed to the W.M.O., asking that Organization to consider the provision of facsimile transmission of meteorological charts specifically intended for reception on board ships. To simplify ships' equipment, the Opinion also asks W.M.O. to consider the use of one standard drum-speed and index of co-operation, the use of class of emission F4 only, and to minimize the number of radio channels. The study of Question 274 has been terminated.

9. **Question 282 (XIII):** Use of a control tone for automatic gain control of receivers in single-sideband radiotelephone systems operating in the HF maritime mobile bands.

Question 282 has been terminated by Report 359, in conjunction with new Recommendation 258-1 (which replaces Recommendation 258 on single-sideband systems in the maritime and aeronautical services). In brief, the Report recommends a continuous control signal, at a level of − 16 dB relative to peak envelope power, for ship-shore and shore-ship transmissions when automatic gain control of receivers is required.

10. **Recommendation 258:** Single-sideband aeronautical and maritime mobile radiotelephone equipments.

This recommendation has been replaced by Recommendation 258-1. The main changes are that both coast and ship station transmitter should have facilities for both classes of emission A3J (suppressed carrier) and A3A (reduced carrier), so that the use of A3A and A3J are of equal standing, and it is intended that the type of emission used by coast stations should be included in the I.T.U. " List of Coast Stations ". A new § *(f)* recognizes that, although the use of class of emission A3J is a desirable objective, it may be necessary to use emission A3A for an indefinite period to obtain acceptable automatic gain control in receivers. A long-term frequency tolerance of ship stations transmitters has been adopted as ± 100 Hz in all HF bands.

The references to the aeronautical services (§ 2) have been brought up to date.

11. **Question 319 (XIII):** Operational procedures for single-sideband radiotelephony systems in the HF maritime mobile bands. (Question 4/XIII).

This new Question was adopted by correspondence after the Interim Meeting, Geneva, 1965. A short Report (360), has been prepared, but further study is necessary. This Question is closely bound up with selective calling and the channels and methods that should be used for calling. It is hoped that further consideration can be given to these matters at the next Interim Meeting in 1967, prior to the maritime W.A.R.C.

12. **Question 320 (XIII):** The introduction of direct-printing telegraph equipment in the maritime mobile service.

This new Question was adopted by correspondence after the Interim Meeting, Geneva, 1965. It has been revised and replaced by Question 5/XIII. Report 361 has been prepared, which summarizes the eleven documents submitted to the XIth Plenary Assembly. Reference should also be made to Report 349. Report 361 concludes that even at this stage it appears that direct printing telegraphy for the maritime service is feasible.

Certain broad recommendations have been made in a new Recommendation 440. In particular it points out that the system must be suitable for operation between pairs of stations and also for broadcasting from one station to several stations; it also recommends that the modulation rate should not exceed 100 bauds and that channel allocations to Administrations for this service should be in frequency blocks 1·5 kHz wide.

Further study and tests are necessary before a firm recommendation can be made on a system for international adoption for maritime purposes.

13. **New Question 6/XIII:** Self-supporting antennae for use on board ships.

The object of this Question is mainly to extend the table of metre-ampères in the Convention for the Safety of Life at Sea, 1960 (Chapter IV, Regulation 9, § *(g)*), which is used in the determination of the " normal range " of the ship's wireless installation. The present table does not cater for the new types of self-supporting antennae.

14. **Cancelled Recommendations:**

Recommendation 424: Bearing and position classification for direction-finding: now covered by Appendix 23 of the Radio Regulations.

Recommendation 426: Spurious emissions from frequency-modulated VHF (metric) maritime mobile equipment: now included in Recommendation 425.

15. Cancelled Reports:

Report 317: Publication of service codes in use in the international telegraph service: redundant; see also Recommendation 437.

16. Amended Recommendations:

Recommendation 77: Reference added to new Recommendation 258-1 on single-sideband maritime and aeronautical radiotelephony systems.

Recommendation 219: § 1.1: deletion of " for minimum period of 6 s ".

Recommendation 429: § *(a)*: misquotation from Safety of Life at Sea Conference corrected.

All Recommendations were amended where necessary to bring references up to date.

17. Terms of Reference of Study Group XIII: The terms of reference were not changed.

TEXTS OF STUDY GROUP XIII

Subject	Maintained	Revised	Minor editorial changes	Deleted	New	Remarks
Codes				Opinion 20 Report 317	Rec. 437	
Selective calling	Rec. 257	Res. 19 Q. 271 SP 371(A) Rep. 320			Res. 19–1 Q. 3/XIII S.P. 3A/XIII Rep. 320–1	
Land mobile equipment		Q. 163 Res. 20 Rep. 319			Q. 7/XIII Res. 20–1 Rep. 319–1 S.P. 7B/XIII S.P. 7A/XIII S.P. 7C/XIII Q. 8/XIII	Channel separation (S.P. 7B/XIII) Technical characteristics (S.P. 7A/XIII) Inter-modulation (S.P. 7C/XIII) MF and HF SSB (Q. 8/XIII)
2 MHz DF		Q. 206 Rec. 428			Q. 2/XIII Rec. 428–1	
Emergency position-indicating radio bacons	Q. 318 *			Op. 21	Rec 439 Op. 25	* Q. 318 has been terminated by Rec. 439 and Op. 25
Signal-to-interference ratios	Q. 272				Rec. 441 * Rep. 358	* Aeronautical service

Subject	Maintained	Revised	Minor editorial changes	Deleted	New	Remarks
A2H, A3H				Q. 273	Rec. 438	
Facsimile				Q. 274	Op. 24	
Control tone for SSB				Q. 282	Rep. 359 *	* See also Rec. 127
Single-sideband				Rec 258	Rec 258–1	
Operational Procedures					Q. 4/XIII Rep 360	
Direct-printing telegraphy		Q. 320			Q. 5/XIII Rec 440 Rep 361	
Self-supporting Antennae					Q. 6/XIII	—
Classification of bearings				Rec 424		
Spurious emissions from VHF equipment				Rec 426		
Interconnections RT alarm signal 8 MHz DF VHF FM equipment 500 kHz interference HF-DF			Rec 77 Rec 219 Rec 423 Rec 425 Rec 429 Rep 93			
Radar interference Voice-operated devices Interference on ships 500 kHz auto alarm Pulse-DF VHF intermodulation Radar identification	Rec 45 Rec 76 Rec 218 Rec 224 Rec 422 Rec 427 Rep 318					

OPINION 24 *

FACSIMILE TRANSMISSION OF METEOROLOGICAL CHARTS FOR RECEPTION ON BOARD SHIPS

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

CONSIDERING

(a) that meteorological charts are being transmitted extensively over radio circuits;

(b) that the transmissions concerned are mainly intended for exchange of meteorological information in the fixed services;

(c) that, however, it is desirable to adopt a more uniform practice for facsimile transmissions of meteorological charts intended for ships;

(d) that Chapter V, Regulation 4*b* (ii), of the Convention for the Safety of Life at Sea, London, 1960, requests contracting Governments to encourage the transmission of suitable facsimile weather charts for ships;

(e) that there is a need for the reception on board ships of suitable meteorological charts;

(f) that an increasing number of ships is being fitted with equipment for receiving meteorological charts;

(g) that the World Meteorological Organization (W.M.O.), in collaboration with the C.C.I.T.T., has standardized the equipment used for international meteorological transmissions (see the following W.M.O. Documentation: Recommendations 60 and 61 of the third session of the Commission for Synoptic Meteorology (C.S.M.) and § 7.15 of the report of the fourth session of C.S.M.);

(h) that the W.M.O. standards provide for various drum-speeds and indices of co-operation; the choice, which depends on the type of charts transmitted, is left at present to the discretion of meteorological services;

(i) that certain characteristics, concerning meteorological facsimile transmissions by radio, are contained in Recommendation 343;

IS UNANIMOUSLY OF THE OPINION

1. that consideration should be given to the provision of facsimile transmission of meteorological charts specifically intended for reception on board ships (see Recommendation 16-IV of the W.M.O. Commission for Maritime Meteorology);

2. that the layout of such charts, the minimum size of letters, figures and symbols, and the thickness of lines, should be standardized throughout the world, to facilitate their interpretation by ships' personnel when using small size recording equipment;

3. that the appropriate signals for preliminary tuning should be transmitted for about 120 seconds prior to the commencement of facsimile transmission of meteorological charts intended for ships;

4. that direct frequency-modulation (F4) should be employed for the facsimile transmission of meteorological charts over radio circuits, with the following characteristics:

(a) Decametric waves (3 MHz – 30 MHz)
Centre frequency (corresponding to the assigned frequency) . . . . . f_0
Frequency corresponding to black . . . . $f_0 - 400$ Hz
Frequency corresponding to white . . . . $f_0 + 400$ Hz

* This Opinion terminates the study of Question 274.

(b) Kilometric waves (30 kHz – 300 kHz)
Centre frequency (corresponding to the assigned frequency) . . . . . f_0
Frequency corresponding to black . . . . $f_0 - 150$ Hz
Frequency corresponding to white . . . . $f_0 + 150$ Hz

5. that consideration should be given to the use of one standard drum speed and one standard index of cooperation in facsimile transmissions specifically intended for reception by ships;

6. that consideration should also be given to keeping to a minimum throughout the world the number of radio frequencies employed for facsimile transmissions intended for reception by ships;

7. that the Director, C.C.I.R. should bring this Opinion to the attention of the W.M.O. for consideration by that Organization.

OPINION 25 *

EMERGENCY POSITION-INDICATING RADIO BEACONS

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

CONSIDERING

(a) that Recommendation 439 defines the characteristics of Emergency Position-Indicating Radio Beacons operating on the frequency of 2182 kHz; to indicate the position of survivors and to facilitate search and rescue operations;

(b) that Doc. XIII/71, 1963–1966, contains Resulotion A. 91 (IV) adopted on 27 September 1965 by the Fourth Session of the Assembly of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) confirming the views of the Maritime Safety Committee; and that, in particular, 2182 kHz is recommended as a first choice operational frequency, but it rests, however, with Administrations to determine whether the beacon should allow for the use of a second or more frequencies;

(c) that Doc. XIII/103, 1963–1966, contains the Report of the Fourth Air Navigation Conference of the International Civil Aviation Organization (I.C.A.O.), Montreal, 9 November – 3 December 1965 in which the frequencies of 121.5 MHz and 243 MHz and certain technical chacracteristics are recommended for Survival Radio Equipment;

IS UNANIMOUSLY OF THE OPINION

1. that the International Civil Aviation Organization be invited to advise C.C.I.R. if they wish the C.C.I.R. to study characteristics of Emergency Position-Indicating Radio Beacons operating on the frequencies of 121.5 MHz and 243 MHz;

2. that the Director, C.C.I.R. be invited to transmit this Opinion to I.C.A.O.

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* This Opinion, together with Recommendation 439, terminates the study of Question 318.

QUESTION 1/XIII *

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS AND MINIMUM FIELD-STRENGTHS REQUIRED IN THE MOBILE SERVICES

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

CONSIDERING

(a) that full effect should be given to the studies which the Administrative Radio Conference, Geneva, 1959, in its Recommendation No. 3, invited the C.C.I.R. to continue for all services;

(b) that for certain kinds of mobile services, partial data relating to interference protection ratios and minimum field strengths required, exist in documents of some Conferences of the I.T.U., for example, in the Final Acts of the International Administrative Aeronautical Radio Conference, Geneva, 1948–1949 and of the Special Regional Conference, Geneva, 1960;

(c) that such documents, however, do not constitute a complete and consistent set of data relating to all kinds of mobile services operating in all frequency ranges, particularly with respect to VHF mobile services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the signal-to-interference protection ratios which define the threshold of harmful interference for the several mobile services;

2. what are the signal-to-noise ratios and the minimum field-strengths required for satisfactory reception of the different classes of emission in the several mobile services;

3. what are the appropriate fading allowances in the several mobile services ?

Note 1. – The above studies should be continued simultaneously and with the same urgency.

Note 2. – Particular attention should be given to those studies which will assist the further refinement of the technical standards used by the International Frequency Registration Board.

Note 3. – The above-mentioned studies should be carried on permanently and recommendations and possible revisions be published as soon as practicable.

QUESTION 2/XIII **

DIRECTION-FINDING AND HOMING IN THE 2 MHz BAND ON BOARD SHIPS

The C.C.I.R., (1959 – 1966)

CONSIDERING

(a) that the use of radiotelephony in the 2 MHz band on board ships is increasing;

(b) that an increasing number of ships are being fitted with direction-finding equipment capable of taking bearings in the 2 MHz band;

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* Formerly Question 272(XIII).

** This Question replaces Question 206.

(c) that the taking of accurate bearings, and especially homing, on board ships is important in cases of distress;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what special technical measures and precautions should be taken in the design and the installation of 2 MHz direction-finding equipment for use on board ships for taking bearings;

2. what are the minimum technical measures that need be taken for homing at the radiotelephony distress frequency of 2182 kHz;

3. what is the order of accuracy to be expected from 2 MHz direction-finding equipment on board ships, particularly at the international distress frequency of 2182 kHz ?

Note. – For the purposes of this Question " homing " means the taking of direction-finding bearings without ambiguity of sense within an arc of 30° on either side of the bow.

RESOLUTION 19-1

SELECTIVE-CALLING SYSTEMS FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICES

(Study Programme 3A/XIII)

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) Question 3/XIII, Study Programme 3A/XIII, Recommendation 257 and Report 320-1;

(b) that the results of the tests carried out by several Administrations are given in the Report of the International Working Party on selective-calling devices (Doc. XIII/19, 1963–1966);

(c) that additional documents considered at the Interim Meeting of Study Group XIII, Geneva, 1965, listed in the conclusions of that Meeting, and documents submitted to the XIth Plenary Assembly, listed in the Chairman's Report (Doc. XIII/107, 1963–1966), give further information;

(d) that so far, it has not been possible to make a decision on the system that should be adopted internationally;

(e) that the selective-calling system should be suitable for operation in all maritime mobile services;

(f) that it is important to standardize, with the least possible delay, the operational and technical characteristics of an international maritime selective-calling system;

UNANIMOUSLY DECIDES

1. that an International Working Party should again be convened for the purpose of further studying selective calling for the maritime mobile service. Reference is made to Question 3/XIII, Study Programme 3A/XIII and Report 320-1, §§ 6, 7 and 8;

2. that the following Administrations and International Organizations should be invited to participate in this International Working Party;

Netherlands (Chairman),	Norway,
Belgium,	Federal Republic of Germany,
Canada,	United Kingdom,
Denmark,	Union of Soviet Socialist Republics,
United States of America	Comité International Radio Maritime,
France	International Chamber of Shipping;
Japan,	

3. that the Netherlands Administration should be invited to be responsible for conducting the tests mentioned in Report 320-1, § 7;

4. that a progress report should be sent, by 1 April 1967, to the Chairman, Study Group XIII and to the Director, C.C.I.R. for circulation to participants in the work of Study Group XIII.

QUESTION 3/XIII *

SELECTIVE-CALLING SYSTEMS FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICES

The C.C.I.R., (1956 – 1963 – 1966)

CONSIDERING

(a) Recommendation 425-1, in answer to Question 107, concerning VHF (metric) FM equipment in the maritime mobile service;

(b) that there may be advantages in the use of selective-calling systems in the operation of the international maritime mobile services;

(c) that a selective-calling system should provide for a sufficiently large number of individual non-conflicting signalling combinations;

(d) that the frequency bandwidth required for signalling should not exceed that required for the transmission of speech;

(e) that the signalling equipment should operate reliably under poor transmission conditions;

(f) that the signal receiving units should be capable of operating with the radio receiving equipment commonly available in ships;

(g) that the transmission of a complete call should be accomplished in as short a time as possible;

(h) that the equipment should be low in cost and capable of operation for long periods under shipboard conditions;

UNANIMOUSLY DECIDES that the following question should be studied:

1. is there a need for a world-wide selective-calling system in the maritime mobile services, and to what extent, and for what purposes can selective calling be used with advantage;

2. what are the advantages and disadvantages in the use of the same selective-calling system in all maritime bands;

3. what are the operational requirements that should be met by any selective-calling system that could be used for the purposes recommended in answer to § 1;

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* This Question replaces Question 271.

4. what auxiliary facilities are available in existing selective-calling systems;
5. what are the essential technical characteristics of selective-calling systems on which international agreement is required;
6. what types of selective-calling systems fulfil the operational and technical requirements in answer to §§ 3 and 5 ?

STUDY PROGRAMME 3A/XIII *

SELECTIVE-CALLING SYSTEMS FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICES

The C.C.I.R., (1959 – 1963 – 1966)

CONSIDERING

(a) that Recommendation 257 does not give a full reply to Question 271;

(b) that the essential technical characteristics of a selective-calling system to be agreed upon need further study, in accordance with Resolution 19-1 and Report 320-1;

(c) that it is desirable to standardize technical and operating characteristics;

UNANIMOUSLY DECIDES that the following study should be carried out:

1. trials of selective-calling systems, with a view to coming to a decision on the type of system that should be adopted internationally;
2. consideration of the number of individual code combinations required and the principles to be adopted in their allocation;
3. determination of those technical and operating characteristics of the selective-calling system which require international standardization;
4. degree of immunity of the systems from false operation and degree of their response to wanted signals.

QUESTION 4/XIII **

OPERATIONAL PROCEDURES FOR SINGLE-SIDEBAND RADIOTELEPHONE SYSTEMS IN THE HF MARITIME MOBILE BANDS

The C.C.I.R., (1965 – 1966)

CONSIDERING

(a) the desirability of encouraging the rapid conversion of the radiotelephone service in the HF maritime mobile bands from-double sibeband (DSB) to single-sideband (SSB) operation (in accordance with Recommendation 258-1);

* This Study Programme replaces Study Programme 271A.

** Formerly Question 319(XIII).

(b) the lack of uniformity of operational procedures among the coast stations that provide this service;

(c) the increasing trend towards the use of unattended or remotely-controlled receivers at coast stations;

(d) the desirability of standardizing, as far as possible, the technical facilities necessary on ships for communicating with different coast stations;

(e) the studies undertaken by the C.C.I.R. in connection with Question 282 on the subject of automatic gain control systems;

(f) the possible use of selective calling devices, particularly in the direction of shore-to-ship (Question 3/XIII);

UNANIMOUSLY DECIDES that the following question should be studied:

1. what special emissions should be made by ship stations using single-sideband equipment when initiating a radiotelephone call to a coast station in the HF maritime mobile service;

2. what further signals, if any, should be sent at the beginning of such a call to enable coast station receivers to be correctly adjusted;

3. is there a need for any supplementary control signals to be sent by the ship station during the radiotelephone call for the purpose of controlling the radio circuit between the ship and the coast station;

4. what special signals or emissions, if any, should be sent by a coast station to initiate a call to a ship station;

5. what special signals or emissions, if any, should be sent by a coast station at the beginning of a radiotelephone call to a ship, to facilitate rapid and accurate adjustment of the ship station receiver;

6. is there a need for any supplementary control signals to be sent by the coast station during a radiotelephone call, for the purpose of controlling the radio circuit between the ship and the coast station ?

QUESTION 5/XIII *

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

The C.C.I.R., (1965 – 1966)

CONSIDERING

(a) that there is a requirement for communication in the maritime mobile service by means of direct-printing telegraph techniques;

(b) that the same information may need to be transmitted simultaneously from one coast station to a number of ship stations;

(c) that ship stations may need to transmit messages and data to coast stations;

(d) that the modulation rates and the telegraph codes used in the telegraph equipment should conform to C.C.I.T.T. standards;

* Formerly Question 320(XIII).

(e) that the use of an error-indicating, an error-indicating and correcting, or an error-correcting system for such circuits may be necessary and that the characteristics of such systems need to be agreed upon;

(f) that any special operating procedures necessary for such a service should be agreed;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what types of error indicating, error indicating and correcting, or error correcting system should be recommended for use over the radio paths;

2. what is the maximum modulation rate that should be used over the radio paths;

3. what types of modulation should be used over the radio paths;

4. what overall quality of transmission (error rate or transmission efficiency factor) is required for this service.

5. what operational procedures should be recommended for such a service ?

QUESTION 6/XIII

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

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

CONSIDERING

(a) that conventional main wire-antennae, suspended between the masts of merchant vessels, impede cargo-handling operations;

(b) that repeated dismantling and re-rigging of main wire-antennae in harbours leads to increased wear and tear and consequently decreases the reliability of the antenna system;

(c) that the superstructure of modern ships makes it more and more difficult to install main wire-antennae of sufficient height and clearance;

(d) that, therefore, the use on board ships of self-supporting main antennae is increasing;

(e) that for several years, efforts have been made to improve the radiation properties and the efficiency of self-supporting antennae, to meet the requirements of the minimum normal range of ship stations in the MF band (Convention for the Safety of Life at Sea, 1960, Chapter IV, Regulation 9, § *(g)*);

(f) that the table of metre-amperes, which appears in the aforementioned Convention and which gives an indication of the normal range obtainable with an installation including a conventional main wire-antenna, cannot be applied to self-supporting antennae;

(g) that experimental work has shown that, in the frequency band 405–535 kHz, self-supporting antennae have, in general, poorer radiation properties than conventional main wire-antennae;

(h) that properly constructed and installed self-supporting antennae, however, have better radiation properties in the 2 MHz bands and HF bands compared with conventional main-wire antennae;

(i) that it is important that antennae and transmitters be suitably matched;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what advice should be offered to the Inter-Governmental Maritime Consultative Organization by the C.C.I.R. on the additions to be made to the table of metre-amperes given in the Convention for the Safety of Life at Sea, 1960, Chapter IV, Regulation 9, § *(g)*, to include self-supporting antennae;

2. what practical methods should be used to assess the properties of self-supporting antennae installed on board a ship in regard to radiation under different conditions, e.g. ship's draught, humidity, precipitation, location and configuration of the antennae;

3. to what extent will it be possible to use the dimensions of the antenna and its height above the deepest load waterline in assessing compliance with the requirements of the said Convention ?

RESOLUTION 20-1

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

(Question 7/XIII)

The C.C.I.R., (1959 – 1963 – 1966)

CONSIDERING

(a) that land mobile services of various kinds are growing rapidly;

(b) that, in border areas, difficulties may arise between the services of different Administrations;

(c) that it would be advantageous if there were a sufficient measure of agreement, where necessary, between Administrations on the characteristics of equipment and on the principles adopted in the planning for land mobile services;

UNANIMOUSLY DECIDES

1. that Administrations should consult together as necessary to resolve any difficulties concerning their land mobile services and for the purpose of improving such services;

2. that those Administrations which are interested in the provision of common land mobile services should consult together and should advise the C.C.I.R. of any technical and operational problems that require international study;

3. that Administrations should continue to submit technical specifications of land mobile equipment and the relevant measuring methods used in their respective countries to the Chairman, Study Group XIII and the Director, C.C.I.R., for circulation;

4. that Administrations should submit information on practices adopted for the allocation of channels between 25 and 500 MHz for land mobile services to the Chairman, Study Group XIII and the Director, C.C.I.R., for circulation;

STUDY PROGRAMME 6A/XIII

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

Performance at 500 kHz

(1967)

The C.C.I.R.,

CONSIDERING

(a) that there are now radically different physical and electrical configurations of self-supporting antennae as compared with the 500 kHz antennae to which Chapter IV, Regulation 9, § (g), of the International Convention for the Safety of Life at Sea, 1960, was intended to apply;

(b) that to provide an adequate answer to Question 6/XIII, additional data are needed as to the design, installation and performance of self-supporting antennae, in order that a proposal might be made for modification of Regulation 9, § (g), to be applicable to self-supporting antennae, while ensuring that such installations will meet the minimum normal ranges specified for ship stations;

DECIDES that the following studies should be carried out:

data on performance of self-supporting antennae should be collected and communicated to the Director, C.C.I.R.:

1. *Description*

1.1 Characteristics and dimensions of antennae as mounted on board ship, e.g. overall height above deepest load line, etc., including simple diagrammatic sketches where appropriate;

1.2 design criteria for base insulator (physical and electrical characteristics, e.g. shunt capacitance, physical dimensions, material, etc.), top loading and loading coil, if any;

2. *Performance*

2.1 Current, as measured with class of emission A0;

2.1.1 current delivered to the antenna system by the transmitter;

2.1.2 current at the base of the antenna;

2.2 Capacitance of the antenna system as seen from the transmitter (at approximately 500 kHz);

2.3 field strength measured over sea water at a distance of at least three nautical miles and adjusted to a reference value at one nautical mile in accordance with Recommendation 368;

2.4 weather conditions on board ship during the measurements;

3. *Installation details, for example :*

3.1 location on ship;

3.2 separation from nearby objects;

3.3 protection from adverse weather effects.

5. that Administrations which have reached agreement with adjacent countries on the operation of land mobile services in border areas, should submit to the C.C.I.R. technical and operational details of the agreement to assist other Administrations with similar problems.

QUESTION 7/XIII *

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

The C.C.I.R., (1956 – 1966)

CONSIDERING

(a) that an interchange of information on the requirements of Administrations, concerning the technical characteristics of equipment used in land mobile services between 25 and 500 MHz, would be advantageous in the development of those services;

(b) that an exchange of information among different countries concerning the practices applied to the assignment of channels and the experience gained in the operation of land mobile services between 25 and 500 MHz is of value in general;

(c) that a certain measure of agreement may be desirable on the characteristics of the land mobile equipment that are used in the border areas of neighbouring countries to minimize mutual interference;

(d) that a certain measure of agreement may also be desirable on the practices governing the allocation and use of channels in land mobile services between 25 and 500 MHz in border areas;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the technical requirements of Administrations concerning equipment used in land mobile services between 25 and 500 MHz that are of international importance in the development of such services, e.g. transmitter power, type of antenna, emission characteristics, frequency tolerance;

2. to what extent would it be desirable to standardize the performance characteristics of land mobile equipment between 25 and 500 MHz internationally;

3. what are the broad practices adopted by Administrations in the allocation of channels to the various kinds of user in the land mobile service between 25 and 500 MHz, e.g. channel separation, geographical spacing of stations in the same adjacent channels, frequency separation for duplex operation, degree of frequency sharing in a particular service area;

4. to what extent is it desirable to reach international agreement on the practices for the allocation of channels in the land mobile service between 25 and 500 MHz ?

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* This Question replaces Question 163.

STUDY PROGRAMME 7A/XIII

TECHNICAL CHARACTERISTICS OF LAND MOBILE EQUIPMENT BETWEEN 25 AND 500 MHz

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

CONSIDERING

(a) that Report 319-1 gives a partial answer to Question 7/XIII.

(b) that information contained in this Report will facilitate cooperation between Administrations in the technical operation of their services;

(c) that a degree of standardization is desirable, since the land mobile service connected to the national network may form part of an international connection, as stated in Recommendation 77-1.

(d) that it is desirable to determine equipment technical characteristics, to facilitate the planning of channel allocation in the land mobile bands;

(e) that it would therefore be desirable to reach agreement upon which are the essential technical characteristics for VHF and UHF radiotelephone equipment for use in the land mobile service, in order to expedite the international interchange of data on such equipment;

UNANIMOUSLY DECIDES that the following studies should be carried out:

determination of equipment characteristics (including methods of measurement) for the various land mobile services between 25 and 500 MHz which may be adopted by Administrations, in particular:

1. for frequency-modulation systems:

1.1 the maximum frequency deviation for various channel-frequency spacings;

1.2 pre-emphasis and de-emphasis characteristics;

2. for amplitude- and frequency-modulation systems:

2.1 the maximum audio-frequency bandwidth;

2.2 frequency tolerances of transmitters;

2.3 typical and maximum output powers of base and mobile-station transmitters;

2.4 mean power limits of harmonic and other spurious emissions:

2.4.1 falling in any other land mobile channel,

2.4.2 falling within the bands of other radio services;

2.5 receiver characteristics, particularly

- frequency stability,
- selectivity,
- radiation,
- intermodulation,
- choice of intermediate-frequency,
- sensitivity,
- audio-frequency response.

Note. – Study Programmes 7B/XIII and 7C/XIII should be borne in mind.

STUDY PROGRAMME 7B(XIII)

MINIMUM CHANNEL-SEPARATION AND OPTIMUM SYSTEMS OF MODULATION FOR LAND MOBILE SYSTEMS BETWEEN 25 AND 500 MHz

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

CONSIDERING

(a) that Report 319-1 partly answers Question 7/XIII;

(b) that congestion in the VHF and UHF bands is a serious problem in many countries;

(c) that this is due to the rapid growth of the land mobile services;

(d) that in a number of countries many base stations are operated from within a limited geographical area;

(e) that the frequency tolerances given in Table I (Column 3) of Report 181-1 are now readily achievable with equipment used in the land mobile service;

(f) that in a number of countries impulse noise is at such a level as to cause serious degradation to communications range;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the minimum bandwidth necessary for various known modulation techniques, in particular for double-sideband amplitude-modulation, frequency modulation and single-sideband emissions;
2. determination of the relative advantages and disadvantages of various types of modulation system as the occupied bandwidth approaches the minimum necessary for the transmission of intelligence, taking into account the necessary signal-to-noise ratio at the receiver input;
3. determination of the minimum channel-separation achievable between base station transmitters located within a limited geographical area or at a common site;
4. determination of the minimum frequency-separation between transmitters and receivers under conditions of duplex operation at the same site;
5. determination of the technical characteristics, criteria and techniques to achieve, in practice, the channel and frequency separations in §§ 3 and 4.

STUDY PROGRAMME 7C/XIII

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

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

CONSIDERING

(a) that Report 319-1 only partly answers Question 7/XIII;

(b) that large numbers of base station transmitters and receivers may be operated within the same limited geographical area;

(c) that such transmitters may produce high-level intermodulation emissions, the odd orders of which fall within and on either side of a land mobile band, and these may fall on receive frequencies of land mobile stations;

(d) that channelling plans can be devised so as to minimize the effects of intermodulation products;

(e) that receivers may have spurious intermodulation responses as a result of two or more strong input signals;

(f) that external non-linearly conducting elements may produce intermodulation products from two or more signals;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the various causes of intermodulation products arising within transmitters, receivers and external non-linear elements, and the various techniques which may be used to minimize their production and reduce their effects, the method used being stated in each case;

2. determination of the maximum permissible mean power of intermodulation emissions for satisfactory operation in the land mobile services;

3. determination of the precautions that are required against the formation of intermodulation products in receivers and which are compatible with satisfactory operation of the land mobile services.

QUESTION 8/XIII

MF AND HF LAND MOBILE SERVICES

Preferred technical characteristics of single-sideband equipment

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

CONSIDERING

(a) that the final report of the Panel of Experts on the reduction of congestion in the HF spectrum has recommended the adoption of single-sideband techniques;

(b) that the necessary bandwidth of single-sideband emissions is less than that for other radiotelephone emissions;

(c) that there is an increasing need for economy in the use of spectrum space;

(c) that the use of single-sideband emissions in the maritime mobile service is under consideration;

(e) that I.C.A.O. is considering the preferred technical characteristics to be adopted for single-sideband equipment for the aeronautical mobile service;

(f) that the need for the use of single-sideband systems for the fixed services has been stressed. (See Radio Regulations No. 465 and Recommendation 100);

(g) that sharing between the land mobile and other services exists in many frequency bands;

(h) that intercommunication between stations in the various mobile services may be necessary, particularly for search and rescue operations;

(i) that it is desirable for common preferred technical characteristics to be adopted, as far as possible, for the maritime, aeronautical and land mobile services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what basic requirements should be met for MF and HF land mobile equipment, in particular the type of single-sideband emission, the sideband which should be used, and the channel separation;

2. what technical performance should be required of the transmitter – in particular, peak envelope power, frequency stability, modulation frequency response, levels of spurious emissions, level of carrier suppression, and restrictions on intermodulation products;

3. what technical performance should be required of the receiver – in particular, selectivity, sensitivity, audio-frequency response, frequency stability, blocking and intermodulation characteristics, and levels of spurious emissions;

4. what other special requirements are necessary for single-sideband equipment used in the MF and HF land mobile service ?

QUESTION 9/XIII

SELECTIVE-CALLING SYSTEM FOR FUTURE OPERATIONAL REQUIREMENTS OF THE MARITIME MOBILE SERVICES

(1967)

The C.C.I.R.,

CONSIDERING

(a) that draft Recommendation D.a * in answer to Question 3/XIII meets the immediate operational requirements of certain Administrations;

(b) that future operational requirements may necessitate the development of different types of selective calling system;

DECIDES that the following question should be studied:

1. what are the operational requirements for selective calling that may be necessary for future maritime communication systems;
2. what other information, in conjunction with the selective call, may be required for the operation of future maritime communication systems;
3. what are the best means for meeting these requirements bearing in mind the technical and economic factors and the need for frequency spectrum conservation?

QUESTION 10/XIII

REDUCTION OF FREQUENCY SEPARATION BETWEEN ADJACENT CHANNELS IN THE VHF (METRIC) MARITIME-MOBILE BAND

(1967)

The C.C.I.R.,

CONSIDERING

(a) that the use of the VHF (156-174 MHz) band by the maritime-mobile service is increasing;

(b) that, as a result, an increased number of channels may be necessary;

(c) that the number of channels available for assignment may be increased by reducing the frequency separation between adjacent channels;

* See the Conclusions of the Special Meeting of Study Group XIII, Geneva, 1967.

(d) that, as there are already in operation a large number of equipments conforming to Recommendation 425, any reduction in frequency separation between adjacent channels needs to be considered, not only as regards technical characteristics but also as regards interference to existing services;

DECIDES that the following question should be studied:

1. if the frequency separation between adjacent channels be reduced to 25 kHz, what should be the technical characteristics of the equipment and what would be the effects on the performance of the radiotelephone system;
2. what special measures would need to be taken to introduce the new frequency separation between adjacent channels with the minimum adverse effect on existing services?

QUESTION 11/XIII

IMPROVEMENTS IN THE PERFORMANCE OF RADIOTELEPHONE CIRCUITS IN THE MF AND HF MARITIME BANDS

(1968)

The C.C.I.R.,

CONSIDERING

(a) that there is a need to improve the quality of transmission of MF and HF maritime radiotelephone circuits;

(b) that the adoption of new compandor principles which have recently become available might offer the prospect of such an improvement;

DECIDES that the following question should be studied:

1. what are the methods by which compandor techniques can be applied to maritime radiotelephone circuits in the MF and HF bands;
2. what improvement in performance is to be expected with these techniques;
3. what characteristics would need to be agreed if such a technique were adopted;
4. what changes, if any, would need to be made to the tolerances of existing equipment, etc. to satisfactorily apply such techniques;
5. what measures should be taken to provide compatible operations between stations utilizing compandor principles and those fitted with conventional equipment only?

QUESTION 12/XIII

RADIO-PAGING * SYSTEMS

(1968)

The C.C.I.R.,

CONSIDERING

(a) that systems for paging by means of radio are in operation in a number of countries and that their use is extending;

(b) that as the areas of coverage are increased, the possibility of interference between different radio-paging systems, and between radio-paging systems on the one hand and other radiocommunication systems on the other hand is increased;

(c) that the various systems already in use, or proposed, are not necessarily compatible one with another;

(d) that system compatibility is necessary in the case of international operation;

(e) that for international operation it is desirable to agree on the parameters of the system;

(f) that it is essential to make the most efficient use of the available radio-frequency spectrum;

DECIDES that the following question should be studied:

1. from a technical point of view, what frequency bands are most suitable for radio-paging systems;

2. what overall quality of transmission (capacity, degree of immunity from false calls, successful call ratio, etc.) should be provided by radio-paging systems;

3. what are the technical characteristics of radio-paging systems on which international agreement is desirable;

4. what operational facilities need to be specified to permit international operation of radio-paging systems, and in what circumstances could they share frequencies with other radiocommunication systems?

* Radio paging—a one-way calling system without speech.

LIST OF DOCUMENTS CONCERNING STUDY GROUP XIII

(Period 1963-1966)

Doc.	Origin	Title	Reference
XIII/1 and Corr.1	United States of America	Selective calling devices for use in the international maritime mobile radiotelephone service – Report of tests performed for the International Working Party set up under Resolution 19	S.P. 271A
XIII/2 and Corr.1	Federal Republic of Germany	Selective calling devices for use in the international maritime mobile radiotelephone service – Report to the International Working Party set up under Resolution 19	S.P. 271A
XIII/3	United Kingdom	Publication of the " Codes and Abbreviations for the International Telecommunication Services " by the International Telecommunication Union	Op. 20
XIII/4	I.M.C.O.	Extract from the Maritime Safety Committee Report to the Council (MSC VIII/28), 8th session	Op. 21
XIII/5	United Kingdom	Tests of selectivity calling devices for use in the international maritime mobile radiotelephone service	Res. 19 Q. 271
XIII/6	I.C.A.O.	Emergency position-indicating radio beacons	Op. 21
XIII/7	United Kingdom	Signal-to-interference protection ratios and minimum field-strengths required in the mobile services – Aeronautical services	Q. 272
XIII/8 and Corr.1	United Kingdom	Use of classes of emission A2H and A3H on the distress frequencies of 500 and 2182 kHz respectively	Q. 273
XIII/9	United Kingdom	Facsimile transmission of meteorological charts for reception by ships	Q. 274
XIII/10	Canada	Selective calling devices for use in the international mobile radiotelephone service – Report to the C.C.I.R. International Working Party on selective calling	S.P. 271A
XIII/11	Canada	Selective calling devices for use in the international mobile radiotelephone service – Report to the C.C.I.R. International Working Party on selective calling	S.P. 271A
XIII/12	United Kingdom	Use of control tone for automatic gain control of receivers in single-sideband radiotelephone systems in the HF maritime mobile bands	Q. 282
XIII/13	France	Selective calling devices for use in the international maritime mobile radiotelephone service – Report to the International Working Party set up under Resolution 19	Res. 19
XIII/14 and Corr.1	The Netherlands	Tests of selective calling devices for use in the international maritime mobile radiotelephone service	Rep. 320 Res. 19
XIII/15	United States of America	Comparative tests of U.S.A., German and Japanese marine selective calling devices	Res. 19 Q. 271

Doc.	Origin	Title	Reference
XIII/16	Japan	Comments on the selective calling devices for use in the international maritime mobile radiotelephone service	Rep. 320 Q. 271
XIII/17	Japan	Test of selective calling devices for use in the international maritime mobile radiotelephone service	Res. 19 Q. 271
XIII/18	Japan	Selective calling devices for use in the international maritime radiotelephone service	Q. 271
XIII/19	International Working Party	Report on selective calling devices	Res. 19 Q. 271 S.P. 271A Rep. 320 Rec. 257
XIII/20	W.M.O.	Facsimile transmission of meteorological charts for reception by ships	Q. 274
XIII/21	Norway	Selective calling devices for use in the international maritime mobile radiotelephone service	S.P. 271A
XIII/22	United Kingdom	Direction finding by ships in the 2 MHz band – Direction finding at 2182 kHz: the use of a 2182 kHz " long line " DF adaptor for use with MF direction finders	Q. 206
XIII/23	United Kingdom	Proposed modifications to Recommendation 428 – Direction finding by ships in the 2 MHz band	Rec. 428
XIII/24	United Kingdom	Characteristics of equipments and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services – Electrical characteristics of amplitude-modulation and angle-modulation land mobile equipment	Q. 163
XIII/25	United Kingdom	Signal-to-interference protection ratios and minimum field strengths required in the mobile services	Q. 272
XIII/26	United Kingdom	Operational procedures for single-sideband radiotelephony in the HF maritime mobile bands	Rec. 258
XIII/27	United Kingdom	Direction finding by ships in the 2 MHz band – Direction finding at 2182 kHz	Q. 206
XIII/28	Federal Republic of Germany	Selective calling devices for use in the international maritime mobile radiotelephone service	Rep. 320 Q. 271
XIII/29	Japan	Characteristics of equipments and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services	Rep. 319
XIII/30	Japan	Fascimile transmission of meteorological charts over radio circuits	Q. 274
XIII/31	Japan	Direction finding by ships in 2 MHz band	Q. 206
XIII/32	Japan	Use of a control tone for automatic gain control of receivers in single-sideband radiotelephone systems operating in the HF maritime mobile bands	Q. 282

Doc.	Origin	Title	Reference
XIII/33 (I/16)	People's Republic of Poland	Proposal for the determination of tolerances for spurious radiation at frequencies above 235 MHz	Rec. 329 S.P. 182(I) Q. 163
XIII/34	United States of America	Revision of Recommendation 258 – Single-sideband aeronautical and maritime mobile radiotelephone equipments	Rec. 258
XIII/35	United States of America	Use of single-sideband in the maritime mobile service for public radiotelephone service to ships and aircraft	Rec. 258
XIII/36	Study Group XIII	Interim Report by the Chairman – Mobile services	
XIII/37	International Working Party on Selective Calling Devices	Measurements on modified selective calling devices working according to the sequential single frequency code (SSFC) system of the Federal Republic of Germany	
XIII/38	Norway	Draft New Question – Transmission of data and teleprinter signals in the maritime mobile service	
XIII/39 and Rev. 1	Federal Republic of Germany	Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services	Q. 163 Res. 20
XIII/40	Federal Republic of Germany	Selective calling devices for use in the international maritime mobile radiotelephone service (Second contribution)	Rep. 320 Q. 271
XIII/41	Federal Republic of Germany	Signal-to-interference protection ratios and minimum field-strengths required in the mobile services	Q. 272
XIII/42	Federal Republic of Germany	Use of classes of emission A2H and A3H on the distress frequencies 500 kHz and 2182 kHz respectively	Q. 273
XIII/43	Federal Republic of Germany	Facsimile transmission of meteorological charts for reception by ships	Q. 274
XIII/44	Federal Republic of Germany	Use of a control tone for automatic gain control of receivers in single-sideband radiotelephone systems operating in the HF maritime mobile bands	Q. 282
XIII/45	C.C.I.R. Secretariat	Submission of Doc. III/82 – Single channel simplex telegraph system for isolated areas and for the mobile services	S.P. 3A(III)
XIII/46	The Netherlands	Effectiveness of A2H emissions on 500 kHz and A3H emissions on 2182 kHz	Q. 273
XIII/47	Japan	Comments on the German selective calling system	
XIII/48	Study Group XIII	Summary record of the first meeting	
XIII/49 and Rev. 1	Working Group XIII-B	Submission of the following proposals to the Interim Meeting of Study Group XIII (Part I)	
XIII/50	C.C.I.R. Secretariat	List of documents issued (XIII/1 to XIII/50)	
XIII/51	Working Group XIII-D	Draft Recommendation – Use of classes of emission A2H and A3H on the distress frequencies 500 kHz and 2182 kHz respectively	Q. 273

Doc.	Origin	Title	Reference
XIII/52	Working Group XIII–B	Submission of the following proposals to the Interim Meeting of Study Group XIII (Part II) – Direction-finding by ships in the 2 MHz band	Q. 206
XIII/53	Working Group XIII–B	Submission of the following proposals to the Interim Meeting of Study Group XIII (Part III) – Emergency position-indicating radio beacons	Draft Q.
XIII/54	Working Group XIII–A	Draft Opinion – Facsimile transmission of meteorological charts for reception by ships	
XIII/55	United States of America	Statement by the Chairman of the delegation	
XIII/56	Working Group XIII–C	Draft amendments to Report 319	
XIII/57	Working Group XIII–C	Draft Recomendation – Signal-to-interference ratios and minimum field-strengths required in the mobile services – Aeronautical services	Q. 272
XIII/58	Working Group XIII–C	Proposed amendments to Report 319	
XIII/58	Working Group XIII–C	Draft Report – Signal-to-interference protection ratios and minimum field-strengths required in the mobile services	
XIII/60	Working Group XIII–D	Proposed modifications to Recommendation 258	
XIII/61	Working Group XIII–D	Draft Question – Operational procedures for SSB radiotelephone systems in the HF maritime mobile bands	
XIII/62	Working Group XIII–A	Draft Recommendation – Selective calling system for use in the international maritime mobile radiotelephone service	
XIII/63	Working Group XIII–E	Draft Question – Application of direct printing telegraph equipment to the maritime mobile service	
XIII/64	Working Group XIII–E	Draft Recommendation – Publication of the “ Codes and Abbreviations for the International Telecommunication Services ” by the International Telecommunication Union	Op. 20
XIII/65	Working Group XIII–D	Draft Report – Use of a control for automatic gain control of receivers in single-sideband radiotelephone systems operating in the HF maritime mobile bands	Q. 282
XIII/66 and Rev.1	Working Group XIII–E	Proposed revision of the texts of Study Group XIII	
XIII/67	Study Group XIII	Summary record of the second meeting	
XIII/68	Study Group XIII	Summary record of the third and last meeting	
XIII/69	C.C.I.R. Secretariat	List of participants	
XIII/70	C.C.I.R. Secretariat	List of documents issued (XIII/51 to XIII/70)	
XIII/71	C.C.I.R. Secretariat	Resolution A.91(IV) of I.M.C.O. – Emergency position-indicating radio beacons	Op. 21
XIII/72	C.C.I.R. Secretariat	Correspondence between W.M.O. and C.C.I.R.	

Doc.	Origin	Title	Reference
XIII/73	C.C.I.R. Secretariat	Letter from the Administration of Senegal	Q. 318, 319, 320
XIII/74	United States of America	Proposed modification to Question 318(XIII) – Emergency position-indicating radio beacons	Q. 318
XIII/75	United States of America	Operational procedures for single-sideband radiotelephone system in the HF maritime mobile bands	Q. 319
XIII/76	United States of America	Selective calling system for use in the international maritime mobile radiotelephone service	Q. 271, S.P. 271A
XIII/77	United States of America	Draft Recommendation – Emergency position-indicating radio beacons	Q. 318
XIII/78	United States of America	Emergency position-indicating radio beacons	Q. 318
XIII/79	United Kingdom	Proposed modification to Draft Recommendation D.c(XIII) – Selective calling system for use in the international maritime mobile radiotelephone service	Draft Rec.
XIII/80	United Kingdom	Characteristics of equipment and principles governing the allocation of channels in VHF (metric) and UHF (decimetric) land mobile services	Q. 163
XIII/81	United Kingdom	Selective calling in the international maritime mobile radiotelephone service	Q. 271
XIII/82	United Kingdom	The introduction of direct printing telegraph equipment in the maritime mobile service – A report on trials of an automatic single-path error-correcting system	Q. 320
XIII/83	F.R. of Germany	Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services	Q. 163
XIII/84	F.R. of Germany	Facsimile transmissions of meteorological charts for reception by ships	Q. 274
XIII/85	F.R. of Germany	Selective calling devices for use in the international maritime mobile radiotelephone service	Rep. 320 S.P. 271A
XIII/86	Denmark	Proposed additions to Report 319 (Annex I)	Q. 163 Rep. 319
XIII/87	Denmark	Emergency position-indicating radio beacons	Q. 318
XIII/88	Japan	Signal-to-interference protection ratios and minimum field-strengths required in the mobile services	Q. 272
XIII/89	F.R. of Germany	Emergency position-indicating radio beacons	Q. 318
XIII/90	Canada	Proposed modification to Draft Recommendation D.d(XIII) – Single-sideband aeronautical and maritime mobile radiotelephone systems	Draft Rec.
XIII/91	Canada	Use of classes of emission A2H and A3H on the distress frequencies 500 and 2182 kHz respectively	Q. 273
XIII/92	Canada	Selective calling devices for use in the international maritime mobile radiotelephone service	Q. 271

Doc.	Origin	Title	Reference
XIII/93	Canada	Proposed modification to Question 320(XIII) – Introduction of direct printing telegraph equipment in the maritime mobile service	Q. 320
XIII/94	Canada	Transmission of data and teleprinter signals in the maritime mobile service	Q. 320
XIII/95	I.F.R.B.	Memorandum by the I.F.R.B. on signal-interference protection ratios and the minimum field strengths necessary in the high frequency maritime mobile service	Q. 272
XIII/96	Switzerland	Specifications for land mobile equipment	Res. 20
XIII/97	Norway	Emergency position-indicating radio beacons	Q. 318
XIII/98	New Zealand	Draft Question – VHF and UHF land mobile services – Minimum channel separation and optimum modulation systems	Draft Q.
XIII/99	New Zealand	Draft Question – VHF and UHF land mobile services – Intermodulation products	Draft Q.
XIII/100	C.C.I.R. Secretariat	List of documents issued (XIII/71 – XIII/100)	
XIII/101	New Zealand	Draft Question – Technical characteristics of VHF and UHF land mobile equipment	
XIII/102	New Zealand	Draft Question – MF and HF mobile services – Preferred technical characteristics of single-sideband equipment	
XIII/103	C.C.I.R. Secretariat	Submission of the Report of the Fourth Air Navigation Conference (I.C.A.O.) (extract)	Op. 21
XIII/104	Canada	Proposed modifications to Draft Recommendation D.d(XIII) – Single-sideband aeronautical and maritime mobile radiotelephone equipments – Response characteristics of maritime mobile radiotelephone equipment	Draft Rec.
XIII/105 (III/107)	The Netherlands	Single channel telegraph system for message broadcasting with error-correcting facility	Draft S.P. Q. 320
XIII/106	The Netherlands	The introduction of direct printing telegraph equipment in the maritime mobile service	Q. 320
XIII/107 and Corr.1	Chairman, S.G. XIII	Report by the Chairman – Mobile services	
XIII/108	Japan	Proposed modifications to Draft Recommendation D.d(XIII) – Single-sideband aeronautical and maritime mobile radiotelephone system	Draft Rec.
XIII/109	Japan	Emergency position-indicating radio beacons	Q. 318
XIII/110	Japan	Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services	Q. 163
XIII/111	Japan	Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services	Q. 163 Res. 20

Doc.	Origin	Title	Reference
XIII/112 (I/51) (VI/189)	C.C.I.R. Secretariat	Submission of the memorandum of the I.F.R.B. – Radio noise in ships	
XIII/113 (III/110)	F.R. of Germany	Factors affecting the quality of performance of complete systems – Full-duplex single-channel ARQ system	S.P. 3A(III)
XIII/114	F.R. of Germany	The introduction of direct printing telegraph equipment to the maritime mobile service	Q. 320
XIII/115	C.I.R.M.	Draft Question – Self-supporting antennae for ships	
XIII/116	France	Characteristics of equipment used in the VHF (metric) and UHF (decimetric) land mobile services	Q. 163 Res. 20
XIII/117	France	Emergency position-indicating radio beacons	Q. 318
XIII/118	France	Single-sideband aeronautical and maritime mobile radiotelephone equipments	Draft Rec.
XIII/119	The Netherlands	Results of practical tests with a full ARQ direct printing telegraph system in the maritime mobile service	Q. 320
XIII/120	Norway	Direct printing telegraph equipment for use in the maritime mobile service – A report on experimental transmission	Q. 320
XIII/121	New Zealand	Annex to Draft Report D.m(XIII)	
XIII/122	Working Group XIII–B	Draft Opinion – Facsimile transmission of meteorological charts for reception by ships	Draft Op. Q. 274
XIII/123	United States of America	Characteristics of equipment and principles governing the allocation of channels in the VHF (metric) and UHF (decimetric) land mobile services – Electrical characteristics of land mobile equipment	Q. 163
XIII/124	Study Group XIII	Summary record of the first meeting	
XIII/125 and Rev.1	Working Group XIII–C	Draft Report – Signal-to-interference protection ratios and minimum field strengths required in the mobile services	Q. 272
XIII/126	Study Group XIII	Draft Recommendation – Emergency position-indicating radio beacons operating on the frequency of 2182 kHz	
XIII/127	Working Group XIII–A	Draft amendment to Recommendation 258 – Single-sideband aeronautical and maritime mobile radiotelephony systems	Q. 162
XIII/128	Working Group XIII–C	Draft Study Programme – Interference due to intermodulation products in the land mobile services between 25 and 500 MHz	Q. 163
XIII/129	Working Group XIII–C	Draft Study Programme – Technical characteristics of land mobile equipment between 25 and 500 MHz	Q. 163
XIII/130	Working Group XIII–C	Draft Study Programme – Minimum channel separation and optimum modulation systems for land mobile systems between 25 and 500 MHz	Q. 163

Doc.	Origin	Title	Reference
XIII/131	Working Group XIII–D	Draft Question – Self-supporting antennae for use by ships	
XIII/132	Study Group XIII	Report – The introduction of direct printing telegraph equipment in the maritime mobile service	
XIII/133	Working Group XIII–A	Draft Report – Operational procedures for SSB radiotelephone systems in the HF maritime mobile bands	Q. 319
XIII/134	Working Group XIII–A	Draft Question – MF and HF land mobile services – Preferred technical characteristics of single-sideband equipments	
XIII/135	Working Group XIII–B	Draft Opinion – Emergency position-indicating radio beacons	Q. 318
XIII/136	Study Group XIII	Summary record of the second meeting	
XIII/137	Working Group XIII–C	Draft amendment to Resolution 20 – Characteristics of equipment and principles governing the allocation of channels between 25 and 500 MHz for land mobile services	Q. 163
XIII/138	Working Group XIII–D	Proposed revision of the texts of Study Group XIII	
XIII/139	Working Group XIII–B	Draft Recommendation – The introduction of direct printing telegraph equipment in the maritime mobile service	Q. 320
XIII/140	Working Group XIII–C	Report – Characteristics of equipment and principles governing the allocation of frequency channels between 25 and 500 MHz for land mobile services	Q. 163
XIII/141	Study Group XIII	Draft Resolution – Selective calling systems for use in the international maritime mobile service	
XIII/142	Study Group XIII	Draft Study Programme – Selective calling systems for use in the international maritime mobile service	
XIII/143	Study Group XIII	Draft Report – Selective calling systems for the international maritime mobile service	Q. 271 and S.P. 271A
XIII/144	Study Group XIII	Draft Question – Selective calling systems for use in the international maritime mobile service	
XIII/145	Working Group XIII–C	Draft Question – Characteristics of equipment and principles governing the allocation of channels in the land mobile services between 25 and 500 MHz	
XIII/146 and Corr.1	Study Group XIII	Summary record of the third meeting	
XIII/147	C.C.I.R. Secretariat	Submission of Docs. III/114, III/115 and III/116	
XIII/148	Study Group XIII	Summary record of the fourth meeting	
XIII/149	Study Group XIII	Summary record of the fifth meeting	
XIII/150	C.C.I.R. Secretariat	List of documents issued (XIII/101 to XIII/151)	
XIII/151	Study Group XIII	Status of texts	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP XIII

Doc.	Title	Final text
XIII/1001	Use of a control tone for automatic gain control of receivers in single-sideband radiotelephone systems operating in the HF maritime mobile bands	Rep. 359
XIII/1002	Facsimile transmission of meteorological charts for reception by ships	Op. 24
XIII/1003	Signal-to-interference ratios and minimum field-strengths required in the mobile services – Aeronautical services above 30 MHz	Rec. 441
XIII/1004	Publication of the " Codes and abbreviations for the international telecommunication services " by the International Telecommunication Union	Rec. 437
XIII/1005	Use of classes of emission A2H and A3H on the distress frequencies 500 kHz and 2182 kHz respectively	Rec. 438
XIII/1006	Direction-finding in the 2 MHz band aboard ships	Rec. 428–1
XIII/1007	Direction-finding and homing by ships in the 2 MHz band	Q. 2/XIII
XIII/1008	Emergency position-indicating radio beacons operating on the frequency of 2182 kHz	Rec. 439
XIII/1009	Emergency position-indicating radio beacons	Q. 318
XIII/1010	Operational procedures for SSB radiotelephone systems in the HF maritime mobile bands	Q. 4/XIII
XIII/1011	Operational procedures for SSB radiotelephone systems in the HF maritime mobile bands	Rep. 360
XIII/1012	Selective calling systems for the international maritime mobile service	Rep. 320–1
XIII/1013	Technical characteristics of land mobile equipment between 25 and 500 MHz	S.P. 7A/XIII
XIII/1014	Minimum channel separation and optimum modulation systems for land mobile systems between 25 and 500 MHz	S.P. 7B/XIII
XIII/1015	Self-supporting antennae for use by ships	Q. 6/XIII
XIII/1016	Emergency position-indicating radio beacons	Op. 25
XIII/1017	Characteristics of equipment and principles governing the allocation of channels between 25 and 500 MHz for land mobile services	Res. 20–1
XIII/1018	Signal-to-interference protection ratios and minimum field strengths required in the mobile services	Rep. 358
XIII/1019	Single-sideband aeronautical and maritime mobile radiotelephony systems	Rec. 258–1
XIII/1020	Interference due to intermodulation products in the land mobile services between 25 and 500 MHz	S.P. 7C/XIII
XIII/1021	MF and HF land mobile services – Preferred technical characteristics of single-sideband equipment	Q. 8/XIII
XIII/1022	Selective calling systems for use in the international maritime mobile service	Res. 19–1
XIII/1023	Selective calling systems for use in the international maritime mobile service	S.P. 3A/XIII

Doc.	Title	Final text
XIII/1024	Selective calling systems for use in the international maritime mobile service	Q. 3/XIII
XIII/1025	The introduction of direct printing telegraph equipment in the maritime mobile service	Q. 5/XIII
XIII/1026	The introduction of direct printing telegraph equipment in the maritime mobile service	Rep. 361
XIII/1027	Characteristics of equipment and principles governing the allocation of frequency channels between 25 and 500 MHz for land mobile service	Rep. 319-1
XIII/1028	The introduction of direct printing telegraph equipment in the maritime mobile service	Rec. 440
XIII/1029	Characteristics of equipment and principles governing the allocation of channels in the land mobile services between 25 and 500 MHz	Q. 7/XIII
XIII/1030	List of documents issued (XIII/1001 to XIII/1030)	

RECOMMENDATIONS OF SECTION H (STANDARD-FREQUENCIES AND TIME-SIGNALS)

RECOMMENDATION 374-1

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/VII)

The C.C.I.R., (1951 – 1953 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that the Administrative Radio Conference, Geneva, 1959, allocated the frequency bands 20 kHz ± 0·05 MHz, 2·5 MHz ± 5 kHz (2·5 MHz ± 2 kHz in Region 1), 5 MHz ± 5 kHz, 10 MHz ± 5 kHz, 15 MHz ± 10 kHz, 20 MHz ± 10 kHz and 25 MHz ± 10 kHz, requesting the C.C.I.R. to study the question of establishing and operating a world-wide standard-frequency and time-signal service;

(b) that additional standard-frequencies and time-signals are emitted in bands 4 to 9;

(c) the provisions of Article 44, Section IV, of the Radio Regulations, Geneva, 1959;

(d) the opinions relating to standard-frequency and time-signal emissions expressed by the International Union of Geodesy and Geophysics (I.U.G.G.) by the International Scientific Radio Union (U.R.S.I.) and by the International Astronomical Union (I.A.U.) and conveyed for information to the Chairman, Study Group VII;

(e) that the standard for measurement of time interval designated by the International Committee of Weights and Measures is based temporarily on a frequency corresponding to a hyperfine energy transition of the Caesium atom given by:

$$f\ (\mathrm{Cs}) = 9\ 192\ 631\ 770\ \mathrm{Hz};$$

UNANIMOUSLY RECOMMENDS

1. that the time-signals emitted from each transmitting station should bear a known relation to the phase of the carrier;

2. that the carrier frequency should be maintained constant with reference to the internationally designated standard for measurement of time interval and that the average daily fractional frequency deviations from the adopted value should not exceed $\pm 1 \times 10^{-10}$;

3. that adjustments in the epoch of the time-signals should be made, with or without a fractional offset in carrier frequency, to maintain the epoch of the time-signals within about 100 ms of Universal Time UT2;

4. that, where a fractional offest is adopted, the value of the offset should be that announced by the B.I.H.:

4.1 that the value of this offset should be changed, when necessary, at 0000 h UT on 1 January of any year;

4.2 that the offset should have the value zero or a positive or negative integral multiple of 50×10^{-10};

4.3 that adjustment in the epoch of the time-signals should be made at the dates announced by the B.I.H.;

4.4 that these adjustments should be made, when necessary, at 0000h UT on the first day of any month, and should be ± 100 ms;

4.5 that the various emissions of this type should be mutually coordinated;

5. that where the carrier frequency is not offset, the time signals should conform to one of the two following schemes:

5.1 the rate of the time signals is offset; in which case the time signals should be coordinated with those referred to in § 4;

5.2 the rate of the time signals is not offset; in which case mutually coordinated experimental emissions should be made, with epoch adjustments made when necessary as announced by the B.I.H.; these adjustments should be made at 0000 h UT on the first day of any month and should be a positive or negative integral multiple of 100 ms;

6. that the B.I.H., after consultation with the observatories and laboratories concerned, should announce the adopted value of the offset;

6.1 that the B.I.H. should also announce the dates and values of adjustments in the epoch of the time-signals;

6.2 that all such announcements should be made by the B.I.H. to the controlling authorities at least six weeks before the changes are to be made;

7. that when corrections are necessary to the epoch of the time-signals emitted from any transmitting station, to maintain an agreed coordination, such corrections should not be made at the same time as the adjustments referred to in §§ 4 and 5;

7.1 that the B.I.H. will suggest to controlling authorities, if necessary, the magnitude and date of such corrections; that all such corrections should be reported subsequently to the B.I.H. and also published as soon as possible.

RECOMMENDATION 375-1

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/VII)

The C.C.I.R., (1959 – 1963 – 1966)

CONSIDERING

(a) that precise intercontinental frequency comparison has already been achieved by the use of the frequency-stable emissions operating in band 4;

(b) that for many purposes a world-wide time (epoch) synchronization with an accuracy greater than 1 ms is required;

(c) that synchronization to 1 μs may be extended to ranges greater than 2000 km by means of pulsed ground-wave signals;

(d) that line-of-sight transmissions in bands 8 and 9, and predominantly ground-wave signals in band 5, provide a stable means of distributing time-signals and standard-frequencies;

UNANIMOUSLY RECOMMENDS

1. that information on the results and methods of measurement of phase stability over paths in bands 4 and 5, should be disseminated as widely as possible;

2. that advantage be taken of the stability and precision of pulsed ground-wave navigation systems, for establishing intercontinental and possibly world-wide time synchronization;

3. that appropriate stations, existing in bands 5 and 6, should be employed as much as possible for distributing standard-frequencies by precise control of their carrier frequencies;

4. that existing FM sound-broadcasting stations and television stations in bands 8 and 9 should be employed as much as possible for distribution of standard-frequency and time-signals,

which can be added to, or make use of, the existing modulation, without interference to the normal programme;

5. that two bands of 100 kHz, in bands 8 and 9 respectively, are suitable for an effective line-of-sight standard-frequency and time-signal service.

RECOMMENDATION 376-I

AVOIDANCE OF EXTERNAL INTERFERENCE WITH EMISSIONS OF THE STANDARD-FREQUENCY SERVICE IN THE BANDS ALLOCATED TO THAT SERVICE

(Question 1/VII)

The C.C.I.R., *(1959 – 1963 – 1966)*

CONSIDERING

(a) the importance and increasing use of standard-frequency and time-signal emissions in the allocated bands;

(b) that interference reduces the usefulness of the standard-frequency and time-signal service to a serious degree;

(c) that, despite the efforts made by Administrations and the I.F.R.B. to clear the standard-frequency bands, some registered users, and many unnotified emissions, remain in these bands, which continue to cause interference with the standard-frequency services;

(d) Recommendation No. 31 of the Administrative Radio Conference, Geneva, 1959;

UNANIMOUSLY RECOMMENDS

1. that to avoid external interference, Administrations and the I.F.R.B. should continue their efforts to clear the standard-frequency bands;

2. that, in the territory under its jurisdiction, each Administration should make every effort to prevent all users of the radio-frequency spectrum from operating other stations in the standard-frequency bands, capable of causing harmful interference to the standard-frequency service;

3. that national monitoring stations should carry out a regular search for external interfering stations in the standard-frequency bands and should make every effort to identify each interfering station, if necessary with international cooperation;

4. that, in each case of external interference, the users of standard-frequency emissions should request the monitoring service of their own country to identify the interfering station;

5. that, in cases of external interference with the standard-frequency service, Administrations should apply the provisions of Articles 14, 15 and 16, of the Radio Regulations, Geneva, 1959, and, if desired, should send a copy of relevant correspondence to the I.F.R.B.;

6. that, when interference is observed in the standard-frequency bands, even if the source cannot definitely be identified, representatives of Administrations, participating in the work of Study Group VII, should exchange information from users of standard-frequency and time-signal transmissions and from the monitoring service. This may later permit identification of the interfering station.

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REPORTS OF SECTION H (STANDARD-FREQUENCIES AND TIME-SIGNALS)

REPORT 267-1 *

STANDARD-FREQUENCIES AND TIME-SIGNALS

(Question 1/VII)

(1956 – 1959 – 1963 – 1966)

This Report outlines the work of Study Group VII since the Xth Plenary Assembly.

Study Group VII, following opinions received from the I.A.U., I.U.G.G. and U.R.S.I., has continued to study the problem of meeting the need for time-signals based on an atomic time scale, as well as for time-signals related to Universal Time. Interference is still a pressing problem and discussions were held between representatives of countries radiating standard-frequency signals in bands 6 and 7 in the European area. Some stations have reduced the periods of audio frequency modulation which can interfere seriously with time-signal reception. Demands for increasing precision posed many technical questions and useful discussions ensued on the possibilities of exploiting new techniques both at low frequencies and in the field of modern communication systems, as indicated in various Study Programmes and Reports.

Recommendation 374–1 concerning standard-frequency and time-signal emissions has been revised with the intention of providing, on the same emission, for the needs of users who require uniform frequency and those requiring time information. Noting that the International Committee of Weights and Measures has now designated a standard for measurement of time interval in terms of an atomic transition, it is recommended that the emitted frequencies be maintained constant to $\pm 1 \times 10^{-10}$ throughout each year by reference to atomic standards. The time-signals should be maintained within about 100 ms of UT2 either by means of step adjustments or by a combination of frequency offset and step adjustments. The B.I.H. is charged with deciding, after due consultation, the extent of the offset in the rate of the time-signals in each year and the magnitude and epoch of the step adjustments and corrections in the offset system. A new Study Programme 1C/VII has been formulated providing for the active study of methods of indicating both the epoch of UT2 and the international unit of time interval in the same emission. Recommendation 374-1 also provides for the coordination of experimental transmissions which do not maintain an offset in carrier frequency but whose time-signals remain within $\pm$ 100 ms of UT2. Coordination of such transmissions will be provided by the B.I.H.

Electromechanical and electronic phase shifters for generating an offset frequency have been used during the last ten years at a number of laboratories and observatories. The development of a pulse operated electronic and solid state phase shifter is noted. Thus there is no technical difficulty in converting from the atomic time scale to another scale with fixed offset, or vice-versa, with negligible error.

In Table I are schedules giving, where appropriate, the daily and hourly patterns of transmission and modulation of stations in the allocated bands. The diagrams of modulation characteristics show why mutual interference exists in many areas: it is particularly severe in Western Europe and in the Far East. Report 269–1 refers to the reduction or elimination of periods of audio-frequency modulation by a number of European transmitters.

* This Report was adopted unanimously.

Other stations JJY, IAM and WWVH retain audio-frequency modulation but reduce interference by introducing gaps in the modulation adjacent to the time-signal pulses. It is hoped that Administrations will continue to make mutual adjustment of their emission and modulation schedules and thereby attempt to secure better use of the standard-frequency bands. Resolution 14–1 indicates the procedure to be followed to avoid the possibility of interference from any new standard-frequency stations and indicates that the information referred to in this Resolution should be published by the I.T.U. and distributed directly to the participants in the work of Study Group VII.

The characteristics of stations operating regular services at controlled frequencies outside the allocated bands are given in Table II. It includes a number of very high-power naval transmitters in band 4 and also a number of emissions in bands 5 and 8.

The Droitwich transmitter at 200 kHz has extended its period of operation to 22 hours per day and has improved the accuracy of the carrier frequency.

Table II includes MSF, which now operates continuously at 60 kHz and the new station HBG, which transmits experimentally at 75 kHz. It is desirable that the HBG time emissions be made regular. Bands 8 and 9 provide a useful means of achieving a local distribution of time and frequency by line-of-sight services and new Opinion 27 suggests that Administrations should reserve 2 bands 100 kHz wide in these bands for this purpose.

In addition to the mutual interference discussed above, effective use of the service is impaired by other transmissions. Interference continues even though the efforts of Administrations and of the I.F.R.B. have effected a considerable clearance of registered transmitters. Recommendation 376–1 urges Administrations to clear the bands by monitoring and if possible identify interfering stations as well as by applying Articles 14, 15 and 16 of the Radio Regulations, Geneva, 1959. In Opinion 28, the I.F.R.B. is asked to increase the number of special monitoring programmes per year and it is also considered desirable that direction-finding information should be obtained on the position of interfering stations.

Report 271-1 concerns the results of propagation studies on a microwave link and also the results obtained in measurements of the phase stability of stations in bands 4 and 5, received at long ranges. In addition it contains information on the fluctuations of reception times of signals received from stations operating in bands 6, 7 and 9.

In the course of examination of the documents submitted it was found that, at present, it is not easy to provide with artificial earth satellites for a general distribution of standard-frequencies and time-signals. The use of standard communication satellites has proved, however, an interesting system for clock synchronization. Study Group VII learned with interest that the communication satellite Relay II had been used in February 1965 to relate clocks in the U.S.A. and Japan with an accuracy of 0·1 μs.

Question 4/VII asks what new techniques would have to be considered for an even better dissemination. Study Programme 1B/VII has been introduced to investigate further the advantages of single-sideband operation with full carrier. Report 362 points out some advantages of this system and indicates the present situation. Study Programme 4A/VII notes the advantages of utilizing existing emissions in the broadcasting bands to disseminate standard-frequencies and time-signals over ground wave range by stabilizing the carrier frequencies and recommends that related studies be made.

Study Programme 3B/VII has been introduced as a result of the increasing precision in several fields of frequency measurement: it is necessary to specify, in convenient and precise terms, the various forms of frequency and phase instability, as, for example, in Report 364.

Some of the work of U.R.S.I. is closely related to improvements in standards and measurement techniques and in the determination of errors introduced in propagation of standard-frequency and time-signals. Other scientific unions, such as I.A.U., I.U.G.G. and I.U.P.A.P. are also discussing problems closely related to Study Group VII, so some advantages are foreseen in arranging discussions (see Resolution 14-1) in collaboration with these Unions.

TABLE I

Characteristics of standard-frequency and time-signal emissions in the allocated bands, valid as of 1 September 1966

Station			Antenna(e)		Number of simultaneous transmissions	Period of operation		Standard-frequencies used		Duration of emission		Accuracy of frequency and time intervals(2) (parts in 10^{10})(2)	Method of adjustment of time-signal
Call sign	Approximate location	Latitude Longitude	Type	Carrier power (kW)		Days/week	Hours/day	Carrier (MHz)	Modulation (Hz)	Time-signal (min)	Audio-modulation (min)		
ATA	New Delhi, India	28° 34′ N 77° 19′ E	Horizontal dipole	2	1	5	5	10	1; 1000	continuous	4 in each 15	±200	Steering by the frequency
FFH(1)	Paris, France	48° 32′ N 02° 27′ E	Radiating mast	5	1	5(6	8 ½	2·5	1; 1000	30 in each 60	25 in each 60	±2	Steps of 100 ms
HBN(1)	Neuchâtel, Switzerland	47° 00′ N 06° 57′ E	Horizontal dipole	0·5	1	7	24	5	1	5 in each 10	nil	±1	Steps of 100 ms
IAM(1)	Roma, Italy	41° 52′ N 12° 27′ E	Vertical λ/4	1	1	6	1	5	1; 1000	10 in each 15	4 in each 15	±1	Steps of 100 ms
IBF(13)	Torino, Italy	45° 02′ N 07° 46′ E	Vertical λ/4	5	1	7	2³/₄	5	1	continuous	nil	±1	Steps of 100 ms
JG2AR(1)	Tokyo, Japan	35° 42′ N 139° 31′ E	Omni-directional	3	1	5(6)	2(7)	0·02	1(8)	continuous	nil	±1	Steps of of 100 ms
JJY(1)	Tokyo Japan	35° 42′ N 139° 31′ E	Vertical λ/2 dipoles; (λ/2 dipole, top-loaded for 2·5 MHz)	2	4	7	24(9)	2·5; 5; 10; 15	1(10); 1000(11)	continuous	27 in each 60	±1	Steps of 100 ms
LOL(1)	Buenos Aires, Argentina	34° 37′ S 58° 21′ W		2	3	6	5	5; 10; 15	1; 440; 1000	4 in each 60	4 in each 5	±200	Steps of 100 ms
MSF(1)	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Horizontal quadrant dipoles; (vertical monopole, 2·5 MHz)	0·5	3	7	24	2·5; 5; 10	1	5 in each 10	nil	±1	Steps of 100 ms
OMA	Praha, Czechoslovak S.R.	50° 07′ N 14° 35′ E	T	1	1	7	24	2·5	1; 1000 (12)	15 in each 30	4 in each 15	±10	Septs of 50 ms
RWM-RES	Moskva, U.S.S.R.	55° 45′ N 37° 18′ E		20	1	7	19	5; 10; 15	1; 1000	10 in each 120(3)	5¹/₄ hours/day(4)	±50	Multiples of 10 ms
WWV(1)	Fort Collins, Colorado U.S.A.	40° 41′ N 105° 02′ W	Vertical λ/2 dipoles	2·5 to 10	6	7	24	2·5; 5; 10; 15; 20; 25	1; 440; 600	continuous (5)	2 in each 5	±0·5	Steps of 100 ms
WWVH(1)	Maui, Hawaii, U.S.A.	20° 46′ N 156° 28′ W	Vertical λ/2 dipoles; (vertical λ/4 for 2·5 and 5 MHz	1 to 2	4	7	24	2·5 5; 10; 15	1; 440; 600	continuous	3 in each 5	±1	Steps of 100 ms
WWVL(1)	Fort Collins, Colorado U.S.A.	40° 41′ N 105° 03′ W	Top-loaded vertical	1·8	1	7	24	0·02	nil	nil	nil	±0·2	nil
ZLFS	Lower Hutt, New Zealand	41° 14′ S 174° 55′ E		0·3	1	1	3	2·5	nil	nil	nil	±500	nil
ZUO(1)	Olifantsfontein, Republic of South Africa	25° 58′ S 28° 14′ E	Vertical monopole	4	1	7	24	5	1	continuous	nil	±5	Steps of 100 ms
ZUO(1)	Johannesburg, Republic of South Africa	26° 11′ S 28° 04′ E	Horizontal dipole	0·25	1	7	24	10	1	continuous	nil	±5	Steps of 100 ms

Notes to Table I

The daily transmission schedule and hourly modulation schedule is given, where appropriate, in the form of Figs. 1 and 2 supplemented by the following notes :

(1) These stations have indicated their participation in the international coordination of time and frequency. The time signals remain within about 100 ms of UT2, and the frequency is maintained as constant as possible by reference to atomic or molecular standards, and at the offset from the nominal value announced for each year by the Bureau international de l'Heure.

(2) Measured with respect to the announced offset in frequency.

(3) Time-signals are radiated according to the following programme :

Minutes past odd hour	*Transmission*
45-46	Call sign
46-50	Seconds, preliminary signal
50-55	No modulation
55-60	Seconds
60-61	Call sign
61-66	Rhythmic signals, 61 per minute

The signals at 06, 08, 10 and 12 hours are transmitted by modulated carrier (A2 signals). At all other times, telegraphic (A1) signals are emitted. RWM-RES does not operate from 0607 to 1345 UT on the first and third Wednesday of each month.

(4) From 0500 to 0807 UT at 5 MHz and from 0830 to 1207 UT at 15 MHz, excluding periods of time-signal transmissions.

(5) In addition to other timing signals and time announcements, a special timing code is radiated 10 times per hour. Consisting of 36 bit, 100 pulse/sec. binary-coded decimal code, it gives the second minute, hour and day of year. A complete time frame lasts one second and the code is broadcast for one minute in each 5-minute period, except the first after the hour. The code contains 100 Hz, 10 Hz and 1 Hz markers, which are locked to the frequency and time-signals.

(6) Monday to Friday.

(7) From 0530 to 0730 UT.

(8) Interruption for 5 ms.

(9) Interrupted from 25-34 minutes of each hour.

(10) Pulse consists of 8 cycles of 1600 Hz tone. First pulse of each minute preceded by 655 ms of 600 Hz tone.

(11) 1000 Hz tone modulation between the minutes 0–10, 20–25, 34–35, 40–45 and 59–60 except 40 ms before and after each second's pulse.

(12) In the period from 1800–0600 UT, audio-frequency modulation is replaced by time-signals.

(13) No offset in the carrier, coordinated time signals.

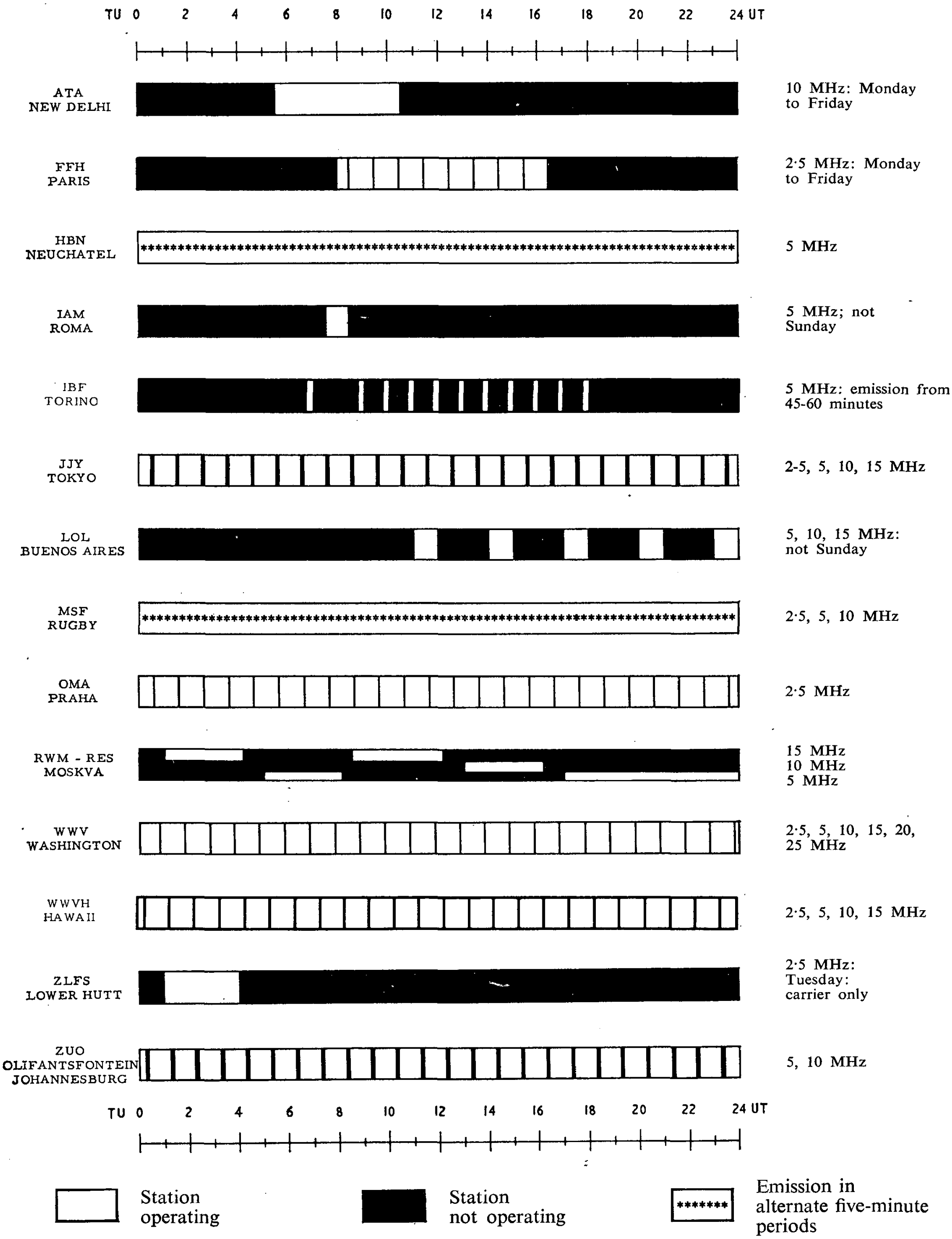
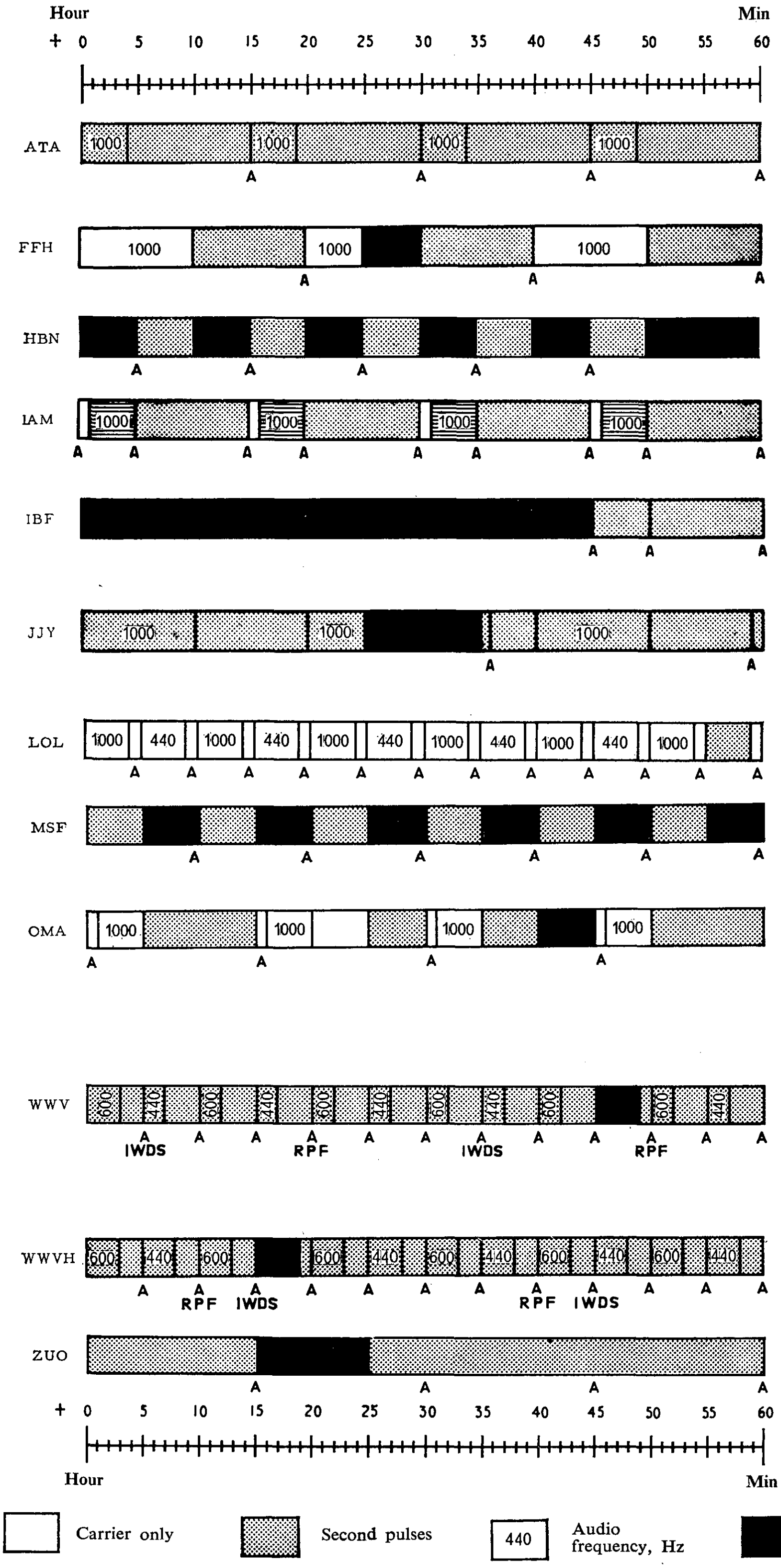


FIGURE 1

Daily emission schedule



Station	Form of second and minute signals morse and voice annoucements (A)
ATA	Pulse of 5 cycles of 1000 Hz tone, lengthened to 100 ms at the beginning of each minute. Call sign and time (UT) in Morse
FFH	Pulse of 5 cycles of 1000 Hz tone: minute pulse followed by 500 Hz tone for 500 ms. Call sign in Morse and voice announcement.
HBN	1 ms carrier break repeated 5 times every second and 250 times at minute, exact time being *start* of first break. Call sign in Morse.
IAM	Pulse of 5 cycles of 1000 Hz tone; minute pulse of 20 cycles of 1000 Hz tone. Call sign and time (UT) in Morse, voice identification.
IBF	Pulse of 5 cycles of 1000 Hz tone repeated 7 times at minute. Call sign and time (UT) in Morse; voice identification at the beginning and end of emission.
JJY	Pulse of 8 cycles of 1600 Hz tone, minute pulse is preceded by a 600 Hz tone of 655 ms duration. Call sign and time (JST) in Morse and voice. Radio propagation warnings in letter code: N (normal), U (unstable) or W (disturbed).
LOL	Pulse of 5 cycles of 1000 Hz tone, 59th pulse omitted. Call sign in Morse: identification and time (UT–3 h) in voice.
MSF	Pulse of 5 cycles of 1000 Hz tone, 100 ms pulse at minute. Call sign in Morse and voice announcement.
OMA	Pulse of 5 cycles of 1000 Hz tone, 100 ms pulse at minute and 500 ms pulse every 5th minute. Last 5 pulses in each quarter hour 100 ms long. From minute 55–60 in every 3rd hour 100 ms pulses lengthened to 500 ms at minutes. Call sign in Morse.
WWV	Pulse of 5 cycles of 1000 Hz tone, 59th pulse omitted and 60th repeated 100 ms later. Radio propagation forecasts given in Morse during each announcement period. Geoalerts given in Morse during first half of 19th minute of each hour. Time code (second, minute, hour and day of year) 10 times per hour. Call sign and time (UT) in Morse; time (UT–5 hours) in voice.
WWVH	Pulse of 6 cycles of 1200 Hz tone, 59th pulse omitted and the 60th repeated 100 ms later. Geoalerts given in morse during first half of 49th minute of each hour. Call sign and time (UT) in Morse; time (UT–10 hours) in voice.
ZUO	Pulse of 5 cycles of 1000 Hz tone, lengthened to about 0·5 s at minute.

FIGURE 2 — *Hourly modulation schedule*

TABLE II

Characterictics of standard-frequency and time-signal emissions in additional bands, valid as of 1 September 1966

Station			Antenna(e)		Number of simultaneous transmissions	Period of operation		Standard-frequencies used		Duration of emission		Accuracy of frequency and time intervals(2) (parts in 10^10)	Method of adjustment of time-signal
Call sign	Approximate location	Latitude Longitude	Type	Carrier power (kW)		Days/week	Hours/day	Carrier (kHz)	Modulation (Hz)	Time-signal (min)	Audio-modulation (min)		
(31)	Allouis, France	47° 10′ N 02° 12′ E	Omni-directionnal	500	1	7	24	164	nil	nil	continuous A3	±0·5	nil
CHU(1)	Ottawa, Canada	45° 18′ N 75° 45′ W	Folded dipoles and rhombic	0·3; 3; 5	3	7	24	3330; 7335; 14 670	1(5)	continuous	nil	±50	Steps of 100 ms
DCF77(24)	Mainflingen, F.R. of Germany	50° 01′ N 09° 00′ E	Omni-directional	12	1	6(6)	6(7)	77·5	1; 200; 440	(8)	(9)	(10)	Steps of 200 ms
(31)	Droitwich, United Kingdom	52° 16′ N 02° 09′ W	T	400	1	7	22	200	nil	nil	A3 broad-cast contin-uously	±5	nil
GBR(1)	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Omni-directional	300 40(3)	1	7	22(11)	16	1(12)	4×5(13) per day	nil	±1	Steps of 100 ms
HBG(34)	Prangins, Switzerland	46° 24′ N 06° 15′ E	Omni-directional	20	1	7	24	75	1(32)	continuous (33)	nil	±0·2	Steps of 100 ms
JJM–6 JG2AS	Kemigawa, Chiba C Japan	35° 38′ N 140° 04′ E	Omni-directional	10	1	7	24	40	nil	nil	nil	±0·5	nil
MSF(34)	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Omni-directional	10	1	7	24	60	1(15)	continuous	nil	±1	Steps of 100 ms
Loran–C	Carolina Beach, N.C., U.S.A.	34° 04′ N 77° 55′ W	Omni-directional	300	1	7	24	100	20(16)	continuous	nil	±0·5	Steps of 50 ms
NAA(1)(25)	Cutler, Maine U.S.A.	44° 39′ N 67° 17′ W	Omni-directional	2000 1000(3)	1	7	24	17·8	nil	nil	nil	±0·5	nil
NBA(1)(26)	Balboa, Panama Canal Zone, U.S.A.	09° 04′ N 79° 39′ W	Omni-directional	300 30(3)	1	7	24(17)	24	1(12)	continuous	nil	±0·5	Steps of 100 ms
NPG/NLK (1)	Jim Creek, Washington, U.S.A.	48° 12′ N 121° 55′ W	Omni-directional	1200 250(3)	1	7	24	18·6	nil	nil	nil	±0·5	nil
NPM(1)	Lualualei, Hawaii, U.S.A.	21° 25′ N 158° 09′ W	Omni-directional	1000 100(3)	1	7	24(18)	26·1	nil	nil	nil	±0·5	nil
NSS(1)	Annapolis, Maryland, U.S.A.	38° 59′ N 76° 27′ W	Omni-directional	1000 100(3)	1	7	24	21·4	nil	nil	nil	±0·5	nil
OMA	Podebrady, Czechoslovak SR	50° 08′ N 15° 08′ E	T	5	1	7	24	50	1(12)	23 hours per day(19)	nil	±10	Steps of 50 ms
RWM–RES	Moskva, U.S.S.R.	55° 45′ N 37° 18′ E		20	1	7	21(20)	100	1	40 in each 120	nil	±50	Multiples of 10 ms
SAZ(24)	Enköping, Sweden	59° 35′ N 17° 08′ E	Yagi (12 dB)	0·1 (ERP)	1	7	24	100 000	nil	nil	nil	±50	nil
SAJ(24)	Stockholm, Sweden	59° 20′ N 18° 03′ E	Omni-directional	0·06 (ERP)	1	1 (21)	2(22)	150 000	nil	nil	10(23)	±1	nil
VNG(27)	Lyndhurst, Victoria, Australia	38° 00′ S 145° 12′ E	Omni-directional	0·5; 0·5–10; 10	2	7	24(28)	5425; 7515; 12 005	1; 1000	(29) continuous	nil	±10	Steps of 100 ms
WWVB(24)	Fort Collins, Colorado, U.S.A.	40° 40′ N 105° 03′ W	Top-loaded vertical	13	1	7	24	60	1(4)	continuous	nil	±0·2	Steps of 200 ms
ZUO	Johannesburg, Republic of South Africa	26° 11′ S 28° 04′ E	Directional to Olifants-fontein	0·05	1	7	24(30)	100 000	1; 100 000	continuous	nil	±5	Steps of 100 ms

NOTES TO TABLE II

(1) These stations have indicated their participation in the international coordination of time and frequency. The time-signals remain within about 100 ms of UT2, and the frequency is maintained as constant as possible by reference to atomic or molecular standards, and at the offset from the nominal value announced each year by the Bureau international de l'Heure.

(2) Measured with respect to the announced offset in frequency.

(3) Figures give the estimated *radiated* power.

(4) Time code used which reduces carrier by 10 dB at the beginning of each second.

(5) Pulses of 200 cycles of 1000 Hz tone : the first pulse in each minute is prolonged.

(6) Monday to Saturday.

(7) Transmission extends essentially from 0645 to 1035 and 1900 to 0010 UT (1 November – 28 February) and from 1900 to 0210 UT (1 March – 31 October).

(8) International type A1 telegraphy time-signals from the Deutsche Hydrographische Institut from 0700 to 0710, 1000 to 1010, 1900 to 1910, 1930 to 1940, 2000 to 2010 UT and during the minutes 00 to 10 of each hour until the end of transmission (see (7)).

A1 telegraphy time-signals (carrier with second pulses) from the Physikalisch-Technische Bundesanstalt from 0728 to 0735, 1028 to 1035, 1911 to 1929, 1941 to 1959 UT and during the minutes 57 to 59 of each hour until the end of the transmission (see (7)).

Carrier with pulses every 2 minutes from the Physikalisch-Technische Bundesanstalt from 0645 to 0659 and 0736 to 0959 UT.

(9) Carrier modulated with 440 Hz tone from 0711 to 0727 and with 200 Hz tone from 1011 to 1027 UT.

(10) The frequency of the controlling oscillator varies by some parts in 10^{10} and increasing slowly at the rate of about 1 part in 10^{9} in one month.

(11) Maintenance period from 1300 to 1430 UT each day.

(12) A1 telegraphy signals.

(13) From 0255 to 0300, 0855 to 0900, 1455 to 1500 and 2055 to 2100 UT.

(14) Maintenance period from 1300 to 1600 UT on the first Sunday of each month.

(15) Carrier interrupted for 100 ms at each second and 500 ms at each minute; from 1430–1530 UT, A2 pulses are transmitted in the same form as for MSF 2·5, 5 and 10 MHz.

(16) Time pulses occur in groups of 8, one millisecond apart; 20 groups per second.

(17) Except from 1300 to 2100 UT on Wednesday.

(18) Except from 1800 to 2300 UT on Wednesday.

(19) From 1000 to 1100 UT, transmission without keying except for call-sign OMA at the beginning of each quarter-hour.

(20) Transmission is interrupted from 0007 to 0100, 1207 to 1300 and 1607 to 1700 UT each day and from 0607 to 1345 UT on the first and third Wednesday of each month.

(21) Each Friday.

(22) From 0930 to 1130 UT.

(23) 5 minutes at the beginning and 5 minutes at the end of the transmission for identification purposes only.

(24) No offset, either on carrier or on time-signals.

(25) FSK is used, alternately with CW, for various intervals each day. It is planned to control the FSK transmissions so that the phase can be tracked, as is now possible for CW.

(26) From November, 1965.

(27) The time-signals are transmitted according to the international coordination. The frequency shall be coordinated at a later date.

(28) Except from 1200 h to 1215 h and 2200 h to 2215 h.

(29) Except first minute of each hour.

(30) No transmissions between 15 and 25 minutes past each hour.

(31) Carrier without offset.

(32) Interruption of the carrier during 100 ms at the beginning of each second; double pulse each minute; triple pulse each hour.

(33) In absence of telegraph traffic.

(34) Experimental emission; no offset in the carrier, coordinated time-signals.

REPORT 269-1 *

REDUCTION OF MUTUAL INTERFERENCE BETWEEN STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/VII)

(1963 – 1966)

The appreciable amount of mutual interference between standard-frequency and time-signal emissions continues to detract from the value of the services operating on the frequencies allocated. The participation of a larger number of stations in the international system for time and frequency coordination, though a most welcome development, has nevertheless caused difficulty in the identification and use of synchronization signals emanating from different stations in the same, small geographical area, in which there is an interval of only one or two milliseconds between the various signals. The position in Western Europe, where this applies, has been improved by the decision of HBN and MSF to coordinate their respective transmission programmes.

The emissions of the time-signals in band 5 (DCF at 77·5 kHz, HBG at 75 kHz, MSF at 60 kHz and OMA at 50 kHz) offer a new way of reducing interference in band 7.

Use of continuous audio-frequency modulation in a number of emissions is a very frequent source of interference with time-signal reception. Audio-frequency modulation, by its very nature, is essentially confined to uses which do not require a high standard of accuracy and it would seem highly desirable to restrict the use of this type of modulation. HBN, IBF and MSF have already eliminated all audio-frequency modulation periods from their programmes. OMA is replacing audio-frequency modulation by time-signals during the period from 1800 to 0600 hours UT. IAM (5 MHz) has reduced the number of audio-frequencies used from three to one (1000 Hz) and the total period of modulation from 40 to 16 minutes per hour.

Other means of finding a solution to the problem of the co-existence of several standard-frequency stations are under study. During the last three years, for instance, WWV and WWVH, in addition to steadily reducing the time allotted to audio-frequency modulation, have introduced a break of 40 ms in continuous modulation, during which time-signals are transmitted.

IAM has also introduced a 40 ms break in continuous modulation, during which time signals are transmitted. In this way there will be neither carrier nor modulation during that interval. This technique has also been employed in Japan, by JJY, the length of the break in modulation being extended to 85 ms to enable time signals to be received from some other synchronized station without interference due to audio-frequency modulation. This method enables sinusoidal modulation to be emitted simultaneously with pulse-modulation without major mutual disadvantages, but it also requires the use of relatively more complex equipment at the receiving station, if the time information is to be satisfactorily extracted.

Though the XIth Plenary Assembly of the C.C.I.R. provided the opportunity for useful discussion between Administrations, it must be stressed that bi- or multi-lateral negotiations between the agencies operating a standard-frequency service might lead to a more direct solution of the problem of interference in restricted areas. If the Chairman and Vice-Chairman, Study Group VII, the Director, C.C.I.R. and the I.F.R.B. were kept informed of such negotiations, they could cooperate in whatever action is to be undertaken.

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* This Report was adopted unanimously.

REPORT 270-1 *

FREQUENCY SPECTRUM CONSERVATION FOR HIGH PRECISION TIME-SIGNALS

(Study Programme 3A/VII)

(1963 – 1966)

There is an increasing number of applications requiring the use of a very precise time reference. In an effort to achieve greater precision, it is to be expected that the system of time distribution will tend to make use of an increased bandwidth up to the limits imposed by the width of the allocated band, the instabilities of the propagation path or by considerations of noise and interference. An increased bandwidth is also appropriate where point-to-point links are used to establish a precise (1 μs or less) time relation between remote stations.

An example of a system developed to exploit fully the characteristics of earth-ionosphere propagation is the navigational system known as Loran-C operating at 100 kHz. This system has been shown to be capable of high precision for the distribution of a time reference. The rate of rise of the leading edge of the signals is chosen to be sufficiently rapid and the length of the pulse is sufficiently short that it is possible to distinguish between the time of arrival of the ground wave and the first ionospheric wave returned from the D-layer. The relative separation of these two components at a distance of about 2000 km has been found experimentally to be 25 to 30 μs. This delay determines the characteristics of the pulse waveform which, necessarily, occupies a total bandwidth of ± 10 kHz.

As a further development, a 1 Hz pulse on Universal Time UT2 has been added experimentally to the transmissions of the Cape Fear station of the Loran-C chain operating on the East Coast of the U.S.A. Similar pulses have been added to the Johnston Island Loran-C station. The purpose of these signals is to make available the time distribution capacity of Loran-C in those cases where the repetition period of the navigational signals is not a simple fraction of a second and these signals cannot, therefore, be easily related to standard time generators.

At high frequencies, where long-distance propagation is wholly dependent upon the ionosphere, the precision with which time-signals can be received is limited by the characteristics of the propagation medium. The bandwidths in use have been largely determined by administrative rather than technical or scientific considerations. It is to be noticed in Report 267-1 (Table I) that all stations, with the exception of HBN and RWM-RES, now make use of an audio-frequency sub-carrier for the time-signal waveform. This takes the form previously recommended by C.C.I.R., and consists of n cycles of 200 n Hz audio-frequency modulation, leading to a pulse of constant length equal to 5 ms. The value of n can be varied conveniently to distinguish the various emissions. Thus WWV and several other stations have adapted a pulse waveform with $n = 5$, i.e. 5 cycles of 1000 Hz. For WWVH, $n = 6$ has been chosen while JJY has recently adopted a pulse with $n = 8$. The use of this form of pulse does not make it possible to resolve the several components of a signal received by more than one path (multipath propagation), but it is reasonably economical of bandwidth, and disturbed propagation conditions produce easily recognizable distortions of the pulse waveform.

A method of precise time dissemination which does not require the use of excessively wide bands has recently been investigated [1]. It makes use of the interference between two closely-spaced phase coherent carrier frequencies to generate a coarse time reference. When this can be realized with sufficient stability it serves, in effect, to identify one particular cycle of the carrier frequency and a precise time reference can then be obtained from measurements of the carrier phase. Experiments making use of the carrier frequencies of 19·9 and 20·0 kHz have shown that at a distance of 1400 km, and with an averaging time of a few hours,

* This Report was adopted unanimously.

that the envelope or group delay variations will cause an instability in the coarse time indication of less than ± 50 μs. This means that a particular cycle of the 20·0 kHz carrier can be " marked ", and used thereafter to provide " microsecond " timing.

In an endeavour to obtain, by means of VLF emissions, a comparable accuracy in the measurement of time epoch as is achieved in the measurement of time interval, studies have begun on the precision which may be attained using very narrow bandwidths (Doc. VII/65 (Italy), 1963-1966).

Two new procedures have been investigated. The first necessitates generation of a particular waveform, which can be interpreted as the product of two sinusoidal signals of the same amplitude, having frequencies in an integral ratio with a convenient phase relation. It takes advantage of the precise timing given by the typical " phase jump " of the radio-frequency signal [2,3] (not of the envelope). The second uses periodic phase inversions of the carrier wave. The theoretical results already obtained are satisfactory and instrument development is in progress.

Another method [4,5] employs, in the same emission (but not necessarily simultaneously), two nearby frequencies. It takes advantage of the precise timing obtainable by a suitable phase-tracking and comparison procedure.

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REPORT 271-1 *

STABILITY AND ACCURACY OF STANDARD-FREQUENCY AND TIME-SIGNALS AS RECEIVED

(Question 3/VII)

(1963 – 1966)

1. Stability of standard-frequency in the VLF and LF bands (bands 4 and 5)

Several reports have been presented on the propagation of VLF signals [1, 2, 3, 4, 5, 6]. The phase of the received signals undergoes a diurnal change due to the altitude variation of the ionospheric D-layer. Consequently, for frequency comparison purposes, the phase should be measured at intervals of 24 hours or multiples thereof.

It has been observed, though, that for great distances the phase-shift accumulated during a 24-hour interval does not necessarily cancel, but can be $\pm 2\pi$ or a multiple thereof. This is due to an interference between two signals of different propagation paths. If the stability

* This Report was adopted unanimously.

of the local frequency standard is sufficient, this situation is easily recognized and taken into account. Such effects have been observed for the signals of GBR, NBA and NPM in Australia and the signals of NBA and NPM in France.

The new time service provided experimentally by the transmitter HBG located near Geneva (see Report 267-1, Table II) reaches a large part of Central Europe. Experiments have shown that the time signal of HBG can be received by simple receivers with a dispersion of less than 0·1 ms at the distance of 1000 km. The phase of the carrier is typically stable to better than $\pm$ 2 μs at the distance of 500 km for ground wave reception.

2. Stability of time-signals in bands 6 and 7 as received

The results of time-signal comparisons carried out at the Tokyo Astronomical Observatory for the years 1961, 1962 and 1963 have been reported [2]. When using a comparison system whose accuracy is $\pm$ 0·01 ms, the standard deviation for a single reception has been found to vary from $\pm$ 0·01 ms at a distance of 4 km to about $\pm$ 0·5 ms at distances of about 18 000 km. Most signals have been found to exhibit little seasonal variation except those from WWV and DAM, when reception becomes poor in thenorthern hem isphere winter.

3. Stability of time-signals in band 9 as received

Measurements have been made in Italy [7] to determine the causes of reduced stability and accuracy of time-signals as received by the users and to establish the statistical distribution of the instability values. The results show that, when using non-specialized equipment, the overall accuracy obtainable is several parts in 10^9, with approximately three consecutive measurements of 1000 seconds duration.

4. Stability over a line-of-sight radio-relay link (band 10)

Experiments have been made [8,9] on the instability introduced by propagation over a 50 km line-of-sight radio-relay link. The results can be summarized as follows:

Concerning the phase of the transmitted wave, the stability degradation due to propagation is less important than the inherent fluctuations in the signal due to the generator noise. For a measurement time period of 1 s, the contribution of instability due to the propagation can be represented by a fractional standard error of about 3×10^{-12} which decreases to 1×10^{-14} as the averaging time is increased to 10^6 s.

Concerning the precision in the transmission of time intervals, the contribution of instability introduced by propagation results in a standard error of about 1×10^{-8} s for time intervals of 1 s and of 2×10^{-6} s for time intervals of 10^6 s.

5. Clock synchronization via satellite

Two experiments have been performed using radio transmissions via artificial satellites to synchronize clocks in different continents. TELSTAR I was used between U.S.A. and U.K. in August 1962, and an accuracy of 1 μs was achieved [10]. Comparisons between U.S.A. and Japan in February 1965 were made using RELAY II and employing the method of retransmission of pulses [11]. An accuracy of synchronization of 0·1 μs was achieved.

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REPORT 362 *

SINGLE-SIDEBAND OPERATION FOR THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICE

(Study Programme 1B/VII)

(1966)

Single-sideband (SSB) operation with full carrier is a special form of emission for reducing mutual interference and has the following advantages:

- the use of an ordinary receiver for the reception of a single transmitting station,
- the possibility, using more elaborate receiving apparatus, of distinguishing between two stations transmitting on the same carrier frequency but using, respectively, the upper or the lower sideband,
- a certain degree of spectrum economy,
- the reduction of second-harmonic distortion, if the carrier is subject to fading.

For a number of years station WWV has been transmitting 440 Hz and 600 Hz audio-frequencies using the standard-frequency carriers of 2·5, 5, 10, 15 and 20 MHz and the upper-sidebands only. All other modulations, time pulses and announcements in voice or in code, were produced by double-sideband amplitude-modulation.

A recent survey of users of WWV indicated that there was insufficient usefulness of the upper single-sideband with full carrier audio-frequency transmissions to justify the equipment necessary to continue the service. Conventional double-sideband audio-frequency transmissions were commenced on 1 March, 1965.

Plans exists to rebuild the station WWV, and perhaps the station WWVH, including transmitters which will be able to furnish the entire programme by single-sideband emissions with full carrier. If found desirable it would then be feasible to operate WWV on the upper sideband and WWVH on lower sideband, thereby making it possible, with appropriate receivers, to differentiate between the two stations.

The Italian station IAM (5 MHz) is continuing the experimental emission of a standard frequency with a 1000 Hz modulation using double-sideband with suppressed carrier. Reception results are satisfactory.

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* This Report was adopted unanimously.

REPORT 363 *

INTERCOMPARISONS OF TIME SCALES BY VARIOUS METHODS

(Study Programme 3C/VII)

(1966)

A number of intercomparisons of standard-frequency generators has been made in recent years. Some of these have employed radio signals. Examples are given in references [1, 2, 3]. Other methods involve the direct comparison of standards, some of which have been carried from one country to another [4, 5]. The results have conclusively shown the value of making such direct comparisons both for checking the effects of propagation on the accuracy of radio transmissions and for studies which may ultimately lead to an international atomic time scale system. Statistical studies of this problem are also being made [6].

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REPORT 364 *

INSTABILITY OF STANDARD-FREQUENCY GENERATORS

(Study Programme 3B/VII)

(1966)

In the last years the results of a large number of studies have appeared on the instability of standard-frequency generators. Theoretical aspects of the problem, definitions and experimental procedures for measurements have been widely investigated.

Several studies [1, 2, 3] have shown that the measurement of the short-term frequency instability of highly stable oscillators is much influenced by low-frequency noise, some of which is known as 1/f noise.

A study [4] of quartz crystal oscillators has shown the existence of several components of frequency instabilities. The use to which an oscillator may be put determines the relative importance of these components. In this study, both long-term (over two months) and short-term characteristics of current good quality oscillators were observed. Corresponding studies have been made for atomic frequency standards [5].

* This Report was adopted unanimously.

A special issue of the Proc. IEEE has been devoted to the frequency stability of oscillators and radio-frequency sources [6] and can be consulted for information.

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REPORT 365 *

COMPARATIVE STATISTICS CONCERNING THE PROPERTIES OF UT AND AT RADIO EMISSIONS

(Study Programme 1C/VII)

(1966)

It is important to determine the best system for supplying both the international unit of time interval and the epoch of UT2 on the same emissions. Two systems which yield such information have been compared for 1965 [1]. This Report presents a summary of some of the results of this study.

The time scales of these systems, UTC (universal coordinated time) and SAB (stepped atomic scale as WWVB), underwent adjustments in their epochs: three for UTC, and four for SAB. If one compares the deviations of the mid-points of the steps from the UT2 scale, the statistical data tabulated in Column 2 in Table I are obtained. If, on the other hand, one compares the deviations from UT2 on weekly basis, the data given in Column 1 in Table I are obtained.

TABLE I

Deviations of scale markers from UT2	Carrier offset	Column 1 Weekly averages : Mean Dev. (ms)	Column 1 Weekly averages : Mean Abs. Dev. (ms)	Column 2 Mid-point averages. Mean Dev. (ms)	Column 2 Mid-point averages. Mean Abs. Dev. (ms)
UTC – UT2	-150×10^{-10}	25·3	34·9	18·6	22·9
SAB – UT2	0	4·1	50·6	8·1	13·1

If one also measures the percentage of the time during the year that the respective scales deviated from UT2 by the amounts given in Column 1 of Table II, one obtains the percentages shown in Column 2 of Table II.

There is little difference in the choice of system on the basis of these statistical data.

* This Report was adopted unanimously.

TABLE II

Column 1	Column 2	
Scale deviation from UT2 exceeded	By the percentage	
	UTC	SAB
0	100	100
25	68	75·5
50	28	47
75	4	23
100	0	7·5
125	0	0

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REPORT 366 *

A METHOD FOR CLASSIFYING SYSTEMS WHICH YIELD TIME AND FREQUENCY INFORMATION FROM THE SAME RADIO EMISSION

(Study Programme 1C/VII)

(1966)

1. Introduction

After the Interim Meeting of Study Group VII, Monte Carlo, 1965, Study Programme 1C/VII was adopted by correspondence. It decided that studies and experiments should be made to provide both epoch of UT2 and the international unit of time interval in the same emission. The present document proposes a method for classifying time and frequency information emission systems chosen for study or adoption.

The Chairman, Study Group VII is requested to communicate with the Chairmen of the appropriate commissions of the U.R.S.I., I.A.U., I.U.G.G. and I.U.P.A.P. It is suggested that anyone having a proposal of a system should submit it in written form to the Chairman of C.C.I.R. Study Group VII for his information and use. After a number of systems have been classified according to the presently suggested scheme [1–6], it may become apparent that some have distinct advantages (simplicity, clarity, completeness of information) over others. At this point, it will be necessary to determine, on the basis of practical tests and stated user needs, which system or systems best meet the needs of users. The Table included in this Report may be used as a guide by proposers of systems.

2. Definitions

2.1 By *carrier offset* is meant an intentional fractional frequency deviation from the nominal carrier frequency value as determined in terms of the frequency:

$$f(\text{Cs}) = 9\,192\,631\,770 \text{ Hz}$$

of the Cesium transition, which has been designated as the international standard of frequency to be employed temporarily for the physical measurement of time. Carrier offset

* This Report was adopted unanimously.

adjustments may be made only on the first of the year for TIC (international coordinated time) emission systems. These are systems which are coordinated by the B.I.H.

2.2 By *time interval offset* is meant an intentional fractional deviation of a period of the broadcast time scale interval from its nominal value in terms of the second of time. Adjustments in time interval offsets may only be made on the first of the year for TIC systems.

2.3 By *an epoch step* is meant an intentional discontinuity introduced at some instant in an otherwise uniform sequence of time intervals, whereby a sequence of intervals following the step does not have the same epoch as that preceding it. Epoch steps may be made only on the first of the month for a TIC system. We classify them into those greater than or equal to 0·2 s., and those less than 0·2 s.

2.4 By the term *UTC marked* is meant sequences of time markers which are offset in time interval and coherent with the offset carrier frequency, and into which epoch adjustments may be introduced, so that they approximate to the UT2 scale within about 0·1 s.

3. Tabular entries

The following instructions are given to help make entries in the Table of § 5. A system which employs more than one carrier or time scale will necessitate the use of more than one table.

3.1 If a carrier offset is *not* present, designate the corresponding entry opposite *A* in the Table by 0. Otherwise designate it by 1. Some carrier signals employed for time dissemination do not have sufficient stability or they have other technological characteristics so that their frequencies do not need to be offset from nominal. In some cases it may not be appropriate to specify the offset to describe the method.

3.2 If a time interval offset is *not* present, designate this fact by writing 0 opposite entry *B*, and otherwise by writing 1.

3.3 If epoch steps 0·2 s or less are used, indicate this opposite entry *C* by 1, and otherwise by 0.

3.4 If UTC markers are *not* present, designate this fact opposite *D* by 0, and otherwise by 1. Note that if the entries under *B* and *C* are both 1, then the entry under *D* is 1 only if the purpose of the adjustments noted in *B* and *C* is to follow UT2 and if the carrier frequency is offset according to the UTC marking method. However, the purpose may be to clarify the signal coding. Hence it is always necessary to make the entry under *D* explicit.

3.5 If voice or code broadcasts are *not* present for the purpose of giving more accurate UT information, then enter 0 under *E*, and otherwise 1.

3.6 If it is not necessary or appropriate to specify a property to classify the system, then the corresponding entry should be left blank (–).

3.7 As examples, the TIC system coordinated by the B.I.H. in 1966 employs the UTC scale and is designated (1111 –) according to this classification method. The SAB scale [7] emitted by WWVB in 1965 and 1966 according to a stepped atomic system approximates UT2 within about 0·1 s. It is designated (00101). The offset atomic system employed by HBG during 1966 employs a scale whose time intervals are offset. It is designated (01100).

4. Scale marker trends

To assist in making the sketch in § 5 according to a uniform method, a few words of clarification are given. A time scale consists of a sequence of markers, often nominal seconds (or minutes). At convenient intervals, count the number of such scale markers and subtract the number of atomic seconds (or minutes) which have occurred since some initial epoch. Plot this number as ordinate, labelled " scale minus time ", against the elapsed time (in months, or years, as convenient) as abscissa. Do this for each time scale present in the system and label the curves clearly. Also choose the appropriate units on the axes.

The slopes of the resulting trends are proportional to the corresponding offsets, in the rates of the time-signals.

5. Classification form

Please prepare items I to V as follows and send the form to the Chairman, C.C.I.R. Study Group VII.

I. *Name of system* (two words)

II. *Name and address of originator*

III. *Table*

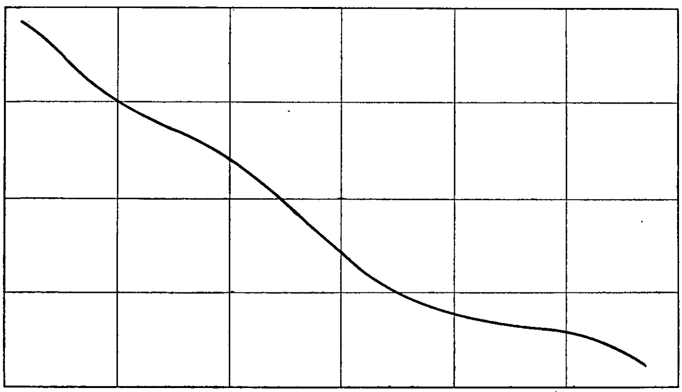
Property	Entry (0 or 1)	Additional remarks
A: Carrier offset		
B: Time interval offset		
C: Epoch steps		
D: UTC marked		
E: UT2 / UT1 } Voice or code(1)		

1 Cross out UT2 or UT1 as appropriate and cross out *Voice* or *Code* as appropriate. Also do this for the label on the UT curve below.

IV. *Sketch of scale marker trends*

(Be sure to indicate the appropriate units on the axes)

Scale minus time (seconds, minutes)



Time (years, month)

V. *Brief general description of system*

BIBLIOGRAPHY

1. C.C.I.R. Doc. VII/70 (U.S.A.), 1963–1966. Some systems for obtaining time and frequency information on radio emissions.
2. C.C.I.R. Doc. VII/71 (U.S.A.), 1963–1966. Possible modifications to the present system of emissions of time and frequency.
3. C.C.I.R. Doc. VII/72 (U.S.A.), 1963–1966. A system for obtaining time and frequency information on radio emissions.
4. C.C.I.R. Doc. VII/73 (U.S.A.), 1963–1966. A simple system for obtaining time and frequency information on radio emissions.
5. C.C.I.R. Doc. VII/74 (U.S.A.), 1963–1966. A method for classifying systems which yield time and frequency information on radio emissions.
6. C.C.I.R. Doc. VII/77 (Italy), 1963–1966. Standard-frequency and time-signal emissions – Proposals for a complete signals schedule.
7. HUDSON, G. E. Scientific aspects of universal and/or atomic time and frequency transmissions, presented to U.R.S.I., Commission I, Washington D.C. (April, 1966). To be published.

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STUDY GROUP VII

(Standard-frequencies and time-signals)

Terms of reference:

Organization of a world-wide service of standard-frequency and time-signal emissions. Improvement of measurement accuracy.

Chairman: Mr. B. Decaux (France)
Vice-Chairman: Professor M. Boella (Italy)

Introduction by the Chairman, Study Group VII

At the XIth Plenary Assembly, Study Group VII brought up to date a number of texts which required amendment owing to the very rapid evolution of the questions they dealt with. It took account of the increasing demands made by users of standard-frequencies and time-signals and of the development of methods for the more accurate production and transmission of such signals. Report 267-1 reviews the work done since the Xth Plenary Assembly; the main points are brought out below.

1. Greater accuracy in transmission and reception

1.1 Recommendation 374-1 reduces the tolerance for the emitted frequency from $\pm 5 \times 10^{-10}$ to $\pm 1 \times 10^{-10}$.

1.2 The same Recommendation indicates the steps to be taken to coordinate such emissions, either by an offset between the frequency emitted and the nominal frequency, so that the time-signals given by the emitted frequency correspond approximately to Universal Time, or without an offset.

1.3 Recommendation 374-1 also extends the role of the B.I.H., which will in future fix for each year not only the value of the offset but also the date on which adjustments in the epoch of the time-signals are to be made.

1.4 The problem of providing UT and the international unit of (atomic) time interval in the same emission is also dealt with in Opinion 26, which advocates on this point the international cooperation already requested in Resolution 14-1. Report 366 gives a method of classifying emissions. Report 365 gives comparative statistics for certain systems now in use.

1.5 Study Programme 3B/VII and Report 364 deal with the definition and improvement of standard-frequency generator stability. Question 4/VII and Study Programme 3C/VII envisage new techniques for international comparison of such generators. Report 363 lists examples of comparisons already performed.

1.6 To avoid any loss in accuracy due to propagation phenomena, Question 2/VII raises the question of the use of bands other than bands 6 and 7. Recommendation 375-1 makes certain recommendations in this connection. Study Programme 4A/VII, supported by Report 271-1, envisages stabilization of the carrier frequencies of sound and television broadcasting stations for this purpose. Lastly, Opinion 27 considers that Administrations should reserve two special bands for standard-frequency and time-signal emissions in bands 8 and 9.

1.7 Greater precision in the distribution of time-signals could be obtained by employing new transmission techniques, such as signals of special form using a narrow VLF band (Study Programme 3A/VII and Report 270-1) or artificial satellites (Study Programme 2A/VII and Report 271-1).

2. **Reduction of interference** with standard-frequency services.

Such interference is of two kinds:

2.1 Mutual interference between standard-frequency stations working on the same frequency. Study Programme 1A/VII and Report 269-1 envisage remedies for this, notably by transmitter time-sharing. Study Programme 1B/VII and Report 362 contemplate employing single sideband operation for this purpose. The use of certain bands, as envisaged in § 1.6 above, might also make the position easier.

2.2 Interference caused by stations other than standard-frequency stations. Recommendation 376-1 impresses once more on Administrations the urgent need to clear the standard-frequency bands. Opinion 28 requests the assistance of the IFRB in this field.

3. **Tables of emission characteristics.** See Report 267-1

RESOLUTION 14-1

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/VII)

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

CONSIDERING

the provisions of Article 44, Section IV, of the Radio Regulations, Geneva, 1959;

UNANIMOUSLY DECIDES

1. that, whenever an assignment to a station operating standard-frequency emissions is put into service, the Administration concerned shall notify this assignment to the I.F.R.B., in accordance with the provisions of Article 9 of the Radio Regulations, Geneva, 1959; however, no notice should be submitted to the I.F.R.B. until experimental investigations and coordination have been completed, in accordance with Article 44, Section IV, of the Radio Regulations;
2. that each Administration should send all pertinent information on standard-frequency stations (such as frequency offset, changes in the phase of time pulses, changes in transmission schedule, etc.), to the Chairman of Study Group VII for forwarding, via the Director, C.C.I.R. to the I.T.U. for official publication;
3. that Study Group VII should cooperate with the I.A.U., the U.R.S.I., the I.U.G.G., the I.U.P.A.P. (International Union of Pure and Applied Physics) and the B.I.H.

OPINION 26

STUDIES AND EXPERIMENTS CONCERNED WITH TIME-SIGNAL EMISSIONS

(Question 1/VII)

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

CONSIDERING

(a) that frequency and epoch may be provided in the same emission;

(b) the present necessity for providing both the epoch of UT and the international unit of time interval in the same emission;

(c) the possible future utilization of an epoch of the atomic time scale in time-signal emissions;

IS UNANIMOUSLY OF THE OPINION

1. that the International Scientific Radio Union (U.R.S.I.), the International Astronomical Union (I.A.U.), the International Union of Geodesy and Geophysics (I.U.G.G.), and the International Union of Pure and Applied Physics (I.U.P.A.P.) should be asked to cooperate

with C.C.I.R. Study Group VII in pursuing studies and experiments relative to the following problems:

1.1 how to provide both the epoch of UT and the international unit of time interval in the same emission;

1.2 how the various essential requirements could be met by the emission of a single uniform time scale;

2. that the Chairman, Study Group VII should communicate with the Chairmen of the appropriate Commissions of the U.R.S.I., the I.A.U., the I.U.G.G., and the I.U.P.A.P., to initiate consultations and that the Director, C.C.I.R. should be informed of the progress of the studies.

QUESTION 1/VII *

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1948 – 1951 – 1953 – 1956 – 1963)

CONSIDERING

(a) that the Administrative Radio Conference, Geneva, 1959, called for the study of the establishment and operation of a world-wide standard-frequency and time-signal service;

(b) that a number of stations are now regularly emitting standard-frequencies and time-signals in the bands allocated by this Conference;

(c) that some areas of the world are not yet adequately served;

(d) that the use of more stations than are technically necessary would diminish the utility of the service by producing harmful interference;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what measures can be recommended for increasing the effectiveness of the existing standard-frequency and time-signal service in the bands allocated by this Conference;

2. what measures can be recommended for the reduction of mutual interference between standard-frequency and time-signal stations operating on the same frequency and whose service areas overlap ?

STUDY PROGRAMME 1A/VII **

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965)

CONSIDERING

(a) that Question 1/VII and Recommendation 374–1 call for information on methods for improving the usefulness of the existing standard-frequency and time-signal service;

(b) that standard-frequency stations are operated simultaneoulsy on the same carrier frequency;

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* Formerly Question 140(VII).

** Formerly Study Programme 140C(VII).

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the possibilities of reducing mutual interference between emissions in this service by:

1.1 shortening the programme of continuous tone modulation and of announcements;

1.2 use of a modulation which gives the required information and accuracy with minimum bandwidth;

1.3 staggering the emissions in the allocated bands and using a convenient type of modulation;

1.4 a convenient coordinated time-sharing of frequencies for those areas where there is mutual interference;

2. collection of information on how standard-frequency emissions in bands 6 and 7 may be coordinated with emissions in other bands to give the best overall world-wide service.

STUDY PROGRAMME 1B/VII *

SINGLE-SIDEBAND OPERATION FOR THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICE

The C.C.I.R., (1965)

CONSIDERING

the measures taken by the I.T.U. urging Administrations to accelerate the conversion of their double-sideband systems, in the frequency bands below 30 MHz, to single-sideband systems and to complete such conversions by 1967 or earlier if possible to reduce the congestion in these bands;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the improvements that may be obtained in the distribution and use of standard-frequency and time-signal emissions by the use of single-sideband operation, with full carrier, particularly in the 2·5; 5; 10; 15; 20 and 25 MHz bands.

STUDY PROGRAMME 1C/VII **

TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965)

CONSIDERING

(a) the necessity for providing both epoch of UT2 and the international unit of time interval in the same emission;

(b) that the epoch of UT is determined by the angular position of the Earth about its axis and is required for various scientific and technical purposes;

* Formerly Study Programme 140D(VII).

** Formerly Study Programme 140E(VII).

UNANIMOUSLY DECIDES that the following studies should be carried out:

the possibility of developing an improved method by active pursuit of studies and experiments to provide both epoch of UT2 and the international unit of time interval in the same emission.

Note. – The international unit of time interval is the second as adopted by the General Conference on Weights and Measures. See also Recommendation 374-1, § *(e)*.

OPINION 27

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/VII)

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

CONSIDERING

(a) that in certain areas, particularly in industrial centres, it is not always possible to obtain an adequate signal-to-noise ratio with the existing standard-frequency and time-signal service;

(b) that a better service is needed in certain areas and this service may be given by use of frequencies in band 8 and higher;

IS UNANIMOUSLY OF THE OPINION

that each Administration should, as far as possible, provide for the distribution of standard-frequencies and time-signals, on a local basis, two bands 100 kHz wide in bands 8 and 9 respectively, the centre frequencies of which should be whole multiples of 5 MHz.

QUESTION 2/VII *

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

The C.C.I.R., (1956 – 1963)

CONSIDERING

(a) that in certain regions, particularly in industrial centres, it is not always possible to obtain an adequate ratio of the wanted signal to the noise level with the existing standard-frequency and time-signal service;

(b) that the bands allocated for standard-frequency and time-signal emissions are more useful for long-distance distribution than for local distribution;

(c) that a better service is needed in certain areas and this service may be given by use of frequencies in band 8 and higher;

* Formerly Question 249(VII).

(d) that high accuracy frequency and time comparisons between distribution centres can be made using frequencies in bands 4 and 5;

UNANIMOUSLY DECIDES that the following question should be studied:

what can be recommended for the distribution of standard-frequencies and time-signals, above 30 MHz and below approximately 100 kHz ?

STUDY PROGRAMME 2A/VII *

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS FROM ARTIFICIAL EARTH SATELLITES

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

CONSIDERING

(a) that continuing advances in communications, particularly in space communications and associated science and technology, have increased the requirements for accuracy and service range of standard-frequency and time-signal emissions;

(b) that the work of Study Group IV describes radiocommunication systems making use of earth satellites which can be expected to give extensive coverage and good stability of signals over the earth's surface;

UNANIMOUSLY DECIDES that the following studies should be carried out:

what are the technical factors to consider in recommending frequencies and in determining the transmitting, modulating and receiving techniques, which are important to the development of standard-frequency and time-signal emissions from artificial earth satellites ?

QUESTION 3/VII **

STABILITY OF STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS AS RECEIVED

The C.C.I.R., (1956 – 1959 – 1963)

CONSIDERING

(a) that the standard-frequency and time-signal emissions as received are less stable than at the source, owing to phenomena occurring in the propagation of radio waves, e.g. the Doppler effect, diurnal variation and multipath interference;

(b) that errors, which occur during propagation, depend on the geographical location of both the transmitter and receiver, as well as on the nature and condition of the medium, and generally differ in different regions of the radio spectrum;

(c) that special techniques of standard-frequency and time-signal emissions may improve the accuracy with which they can be received;

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* Formerly Study Programme 249A(VII).

** Formerly Question 250(VII).

(d) that the accuracy with which standard-frequency and time-signal emissions can be received may depend upon the design of the receiving equipment;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the causes of the reduction in the stability and accuracy of the standard-frequencies and time-signals as received by the users;
2. what is the magnitude in statistical terms of the instability introduced by these causes;
3. what are the most suitable techniques for transmitting and receiving standard-frequencies and time-signals to obtain the best results in the reception of:
   - standard-frequencies and time-signals as used by those requiring moderate accuracy;
   - standard-frequencies and time-signals as used by those requiring the maximum possible accuracy ?

STUDY PROGRAMME 3A/VII *

FREQUENCY-SPECTRUM CONSERVATION FOR HIGH PRECISION TIME-SIGNALS

The C.C.I.R., (1959)

CONSIDERING

(a) that higher precision in the radio distribution of time-signals necessitates, using present techniques, the use of an increased bandwidth;

(b) that newly developed techniques may, nevertheless, effect a considerable bandwidth economy;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the relationship between bandwidths required, and precisions obtainable at present for various carrier-to-noise ratios as may be encountered in practice;
2. an investigation of narrow-band techniques to generate and broadcast high precision time markers;
3. an investigation of the characteristics of the radio paths involved that limit the accuracy of time-signals as received, and how these radio-path parameters affect the choice of an optimum method.

STUDY PROGRAMME 3B/VII *

INSTABILITY OF STANDARD-FREQUENCY GENERATORS

The C.C.I.R., (1965)

CONSIDERING

that the employment of high quality frequency standards in a wide range of applications has given rise to a need to specify, in convenient and precise terms, the various forms of frequency and phase instability which limit performance in relation to the increasingly stringent requirements;

* Formerly Study Programme 250A(VII).

* Formerly Study Programme 250C(VII).

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. how may the various forms of frequency and phase instability, inherent in a standard-frequency generator, be qualitatively described;
2. how may the limitations of precision, imposed by various forms of frequency and phase instability in a standard-frequency generator, be quantitatively expressed ?

STUDY PROGRAMME 3C/VII *

INTERNATIONAL COMPARISON OF STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965)

CONSIDERING

(a) that many stations participate in the international coordination of frequency and time;

(b) that U.R.S.I. Resolution No. 2 adopted in Tokyo, 1963, at its XIVth General Assembly and the I.A.U. resolutions adopted at Hamburg, 1964, during its XIIth General Assembly, recommend that international comparisons be made between the scales of time in use;

UNANIMOUSLY DECIDES that the following studies should be carried out:

international comparisons between standard-frequency and time-signal emissions by different methods (exchange of standard-frequency and time pulse generators, transmissions over radio-relay links, transmission by artificial earth-satellites, etc.).

QUESTION 4/VII **

DISSEMINATION OF STANDARD-FREQUENCIES AND TIME-SIGNALS

The C.C.I.R., (1965)

CONSIDERING

(a) the needs for increased accuracy of standard-frequency and time-signals;

(b) that the present standard-frequency and time-signal emissions as received are less accurate than the source, due to effects in the propagation of the radio waves, such as diurnal variations and the Doppler effect;

UNANIMOUSLY DECIDES that the following question should be studied:

what additional techniques can be employed for disseminating standard-frequencies and time-signals by radio-transmissions (for example: by reflections from meteor trails, utilization of existing broadcasting facilities and laser techniques) ?

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* Formerly Study Programme 250D(VII).

** Formerly Question 289(VII).

STUDY PROGRAMME 4A/VII

DISSEMINATION OF STANDARD-FREQUENCIES BY CARRIER-FREQUENCY STABILIZATION OF BROADCASTING EMISSIONS

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

CONSIDERING

(a) the need for investigation of additional techniques for the dissemination of standard-frequencies and time-signals;

(b) that broadcasting of standard-frequency signals is carried out in some countries by stations in the broadcasting bands;

(c) that certain advantages may be obtained by the technique of stabilizing the carrier-frequencies of broadcasting stations, namely:

- the possibility of providing good ground-wave coverage, free of Doppler-effect errors, at centres of population and industry;
- the rapid comparison of frequencies at receiving locations by the use of such sufficiently high carrier-frequencies; and
- the use of relatively simple receiving equipment;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the accuracy and stability of received signals from such broadcasts;
2. investigation of the influence of the location of transmitting stations on convenience of use and on propagation characteristics of signals;
3. determination of the desirability of establishing a service of this nature;
4. investigation of the relative merits of amplitude- and frequency-modulation as related to the dissemination of time-signals and of the use of the broadcasting bands for the dissemination of standard-frequencies by carrier-frequency stabilization.

OPINION 28

SPECIAL MONITORING CAMPAIGNS BY THE I.F.R.B. WITH A VIEW TO CLEARING THE BANDS ALLOCATED EXCLUSIVELY TO THE STANDARD-FREQUENCY SERVICE

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

CONSIDERING

(a) Recommendation No. 31 of the Administrative Radio Conference, Geneva, 1959, and the results of the special monitoring campaigns organized by the I.F.R.B., with a view to clearing the bands allocated exclusively to the standard-frequency service;

(b) the need for achieving a more complete clearance of those bands;

(c) the difficulty experienced by the I.F.R.B. in identifying stations not belonging to the standard-frequency service, but operating in the standard-frequency bands;

IS UNANIMOUSLY OF THE OPINION

1. that the I.F.R.B. should be asked to increase, as far as practicable, the number of special monitoring programmes per year, covering the bands allocated exclusively to the standard-frequency service;

2. that the I.F.R.B. should urge Administrations of countries where direction-finding facilities are available to take bearings with a view to determining the position of the stations observed.

QUESTION 5/VII

HIGH PRECISION STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS *

(1968)

The C.C.I.R.,

CONSIDERING

(a) that there is a growing need, particularly in aviation, for accuracies of standard-frequency and time-signal emissions that exceed those currently available;

(b) that to achieve world-wide uniformity, timing requirements for aviation should be closely coordinated with the International Civil Aviation Organization (I.C.A.O.);

DECIDES that the following question should be studied:

what methods can be internationally adopted to provide, on a world-wide basis, standard-frequency and time-signal emissions with synchronization uncertainties of 0·5 μs or less (3σ)?

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* See draft Report H.n (VII).

LIST OF DOCUMENTS CONCERNING STUDY GROUP VII

(Period 1963-1966)

Doc.	Origin	Title	Reference
VII/1	C.C.I.R. Secretariat	Resolution 15 of the International Association of Geodesy	
VII/2	United Kingdom	Standard-frequency and time-signal emissions	Q. 140
VII/3	United Kingdom	Standard-frequency and time-signal emissions	S.P. 140A
VII/4	United Kingdom	Single-sideband operation for the standard-frequency and time-signal service	S.P. 140B
VII/5	United Kingdom	Standard-frequency and time-signal emissions in additional frequency bands	Q. 249
VII/6	C.C.I.R. Secretariat	Resolution 21 of the International Association of Geodesy	
VII/7	Australia	Accuracy of reception of VLF emissions	Q. 250
VII/8	Australia	Stabilized frequency emissions and monitoring facilities in bands 4 and 5	Proposed mod. to Rep. 268
VII/9	France	Standard-frequency and time-signal emissions	Rec. 374 Q. 140
VII/10	France	Standard-frequency and time-signal emissions	Rec. 376 S.P. 140A
VII/11	France	Standard-frequency and time-signal emissions in additional frequency bands	Rec. 375 Q. 249
VII/12	C.C.I.R. Secretariat	Clarification and Resolutions of the International Astronomical Union	
VII/13	U.R.S.I.	Resolution 1 of the XIVth General Assembly, Tokyo, 1963, Commission I – Radio standards and measurements	U.R.S.I. Res. 1
VII/14	U.R.S.I.	Resolution 2 of the XIVth General Assembly, Tokyo, 1963, Commission I – Radio standards and measurements	U.R.S.I. Res. 2
VII/15	United States of America	Standard-frequency and time-signal emissions	Proposed mod. to Res. 14
VII/16 and Corr.1	United States of America	Dissemination of standard-frequencies and time-signals	Draft S.P.
VII/17	United States of America	Time-signal emissions	Draft Q.
VII/18	United States of America	Studies and experiments concerned with time-signal emissions	Draft Op.
VII/19 and Corr.1	United States of America	International comparison of standard-frequency and time generators	Draft S.P.
VII/20	Japan	JJY standard-frequency and time-signal emissions	Q. 140
VII/21	Japan	Stability of standard-frequency and time-signal emissions as received	Q. 250
VII/22	Japan	Measurement of short-term instability and frequency spectra of highly stable quartz oscillators	Q. 250

Doc.	Origin	Title	Reference
VII/23	Chairman Study Group, VII	Interim Report by the Chairman, Study Group VII (Standard-frequencies and time-signals)	
VII/24	United Kingdom	Standard-frequency and time-signal emissions from artificial earth satellites	S.P. 249A
VII/25	United Kingdom	Instability of standard-frequency generators	S.P. 250B
VII/26	United States of America	Standard-frequencies and time-signals	Q. 140 Proposed mod. to Rep. 267
VII/27	United States of America	Standardized frequency emissions and monitoring facilities in bands 4 and 5	Q. 249 Rec. 375 Proposed mod. to Rep. 268
VII/28	Italy	Time-signal reception in band 9	Q. 250
VII/29	Italy	Improved distribution of time-signals	Rec. 375 Q. 249 S.P. 250A
VII/30	I.F.R.B.	Special monitoring programmes covering the frequency bands allocated exclusively to the standard-frequency service	
VII/31	Italy	The new IBF schedule	
VII/32	Study Group VII	Summary record of the first meeting	
VII/33	Working Group VII–B	Deletion of Report 258	
VII/34	Working Group VII–B	Revision of Recommendation 376	
VII/35	Working Group VII–A	Single-sideband operation for the standard frequency and time-signal service	
VII/36	Working Group VII–B	Standard-frequency and time-signal emissions	Mod. to Res. 14
VII/37	Working Group VII–B	Revision of S.P. 140A(VII)	
VII/38	Working Group VII–B	Draft Opinion	
VII/39	Working Group VII–B	Studies and experiments concerned with time-signal emissions	Draft Op.
VII/40	Workinh Group VII–A	Draft Study Programme–Time-signal emissions	Draft S.P.
VII/41	Working Group VII–A	Standard-frequency and time-signal emissions	Draft Rec.
VII/42	Working Group VII–A	Instability of standard-frequency generators	Draft S.P.
VII/43	Working Group VII–A	Frequency spectrum conservation for high precision time-signals	Draft Rep.
VII/44	Working Group VII–A	Instability of standard-frequency generators	Draft Rep.
VII/45	Working Group VII–A	Dissemination of standard-frequencies and time-signals	Draft Q.
VII/46	Working Group VII–A	Stability and accuracy of standard-frequency and time-signals as received	Draft mod. to Rep. 271
VII/47	Working Group VII–B	Standard-frequency and time-signal emissions in additional frequency bands	Draft Op.
VII/48	Working Group VII–B	International comparison of standard-frequency and time-signal transmissions	Draft S.P.

Doc.	Origin	Title	Reference
VII/49	Working Group VII-A	Standard-frequency and time-signal emissions in additional frequency bands	Draft Rec.
VII/50	C.C.I.R. Secretariat	List of documents issued (VII/1 to VIII/50)	
VII/51	Working Group VII–A	Single-sideband operation for the standard-frequency and time-signal service	Draft Rep.
VII/52	Working Group VII–B	Reduction of mutual interference between standard-frequency and time-signal emissions	Draft Rep.
VII/53	Study Group VII	Summary record of the second meeting	–
VII/54	Study Group VII	Modifications to Table I	Rep. 267
VII/55	Study Group VII	Standard-frequencies and time-signals	Draft Rep.
VII/56	Study Group VII	Summary record of the third and last meeting	
VII/57 (IV/166) (VIII/67) (IX/159)	C.C.I.R. Secretariat	List of participants – Interim meetings (Monte-Carlo, 1965)	
VII/58	C.C.I.R. Secretariat	List of documents issued (VII/51 to VII/58)	
VII/59	Czechoslovak S.R.	Elimination of tone modulation of station OMA on 2·5 MHz	Rep. 269 Rep. 267 S.P. 140A Q. 140
VII/60	United Kingdom	Dissemination of standard-frequencies and time-signals	Q. 289 Draft Rep.
VII/61	United Kingdom	Standard-frequency and time-signal emissions in additional frequency bands	Q. 249 Draft Rep.
VII/62 and Corr.1	United States of America	A precision pulse-operated electronic phase shifter and frequency translator	S.P. 140E
VII/63 and Corr.1	United States of America	Draft Study Programme – Dissemination of standard-frequencies by carrier-frequency stabilization	
VII/64	Italy	IBF station	S.P. 140C
VII/65	Italy	Time-signal emissions with spectrum conservation in the VLF band	Q. 249 S.P. 250A
VII/66	Japan	Report on an experiment on clock-pulse synchronization using "Relay II" satellite	Q. 250 S.P. 250D
VII/67	Japan	Proposed modifications to Draft Report H.d(VII) – Standard-frequencies and time-signals	Draft Rep.
VII/68	Japan	Report on standard-frequency broadcast at station JJM–6/JG2AS	Draft Rec. Draft Rep.
VII/69	Australia	Proposed modification to Draft Recommendation H.a(VII) – Standard-frequency and time-signal emissions	Draft Rec.

Doc.	Origin	Title	Reference
VII/70	United States of America	Some systems for obtaining time and frequency information on radio emissions	S.P. 140E Draft Op.
VII/71	United States of America	Possible modifications to the present system of emissions of time and frequency	S.P. 140E Draft Op.
VII/72	United States of America	A system for obtaining time and frequency information on radio emissions	S.P. 140E Draft Op.
VII/73	United States of America	A simple system for obtaining time and frequency information on radio emissions	S.P. 140E Draft Op.
VII/74	United States of America	A method for classifying systems which yield time and frequency information from the same radio emission	S.P. 140E
VII/75	Chairman, Study Group VII	Report by the Chairman, Study Group VII – Standard-frequencies and time-signals	
VII/76	Switzerland	Standard-frequency and time-signal transmissions by HBG	Q. 140
VII/77	Italy	Standard-frequency and time-signal emissions – Proposals for a complete signals schedule	Draft S.P. 140E Draft Op.
VII/78	Study Group VII	Summary record of the first meeting	–
VII/79	Working Group VII–A	Draft Study Programme – Dissemination of standard-frequencies by carrier frequency stabilization of broadcasting and television emissions	–
VII/80	Working Group VII–A	Modification to Draft Report H.i(VII) – Single-sideband operation for the standard-frequency and time-signal service	S.P. 140B
VII/81	Working Group VII–A	New text Draft Report H.g(VII) – Stability and accuracy of standard-frequency and time-signals as received	Q. 250
VII/82 and Corr.1	Study Group VII	Draft Report – Intercomparisons of time scales by various methods	S.P. 250D
VII/83	Study Group VII	Proposed new text of Draft Report H.h(VII) – Instability of standard-frequency generators	S.P. 250B
VII/84	Study Group VII	Proposed modifications to Draft Recommendation H.a(VII) – Standard-frequency and time-signal emissions	
VII/85 and Rev.1	Study Group VII	Draft Report – Comparative statistics concerning the properties of UT and AT radio emissions	S.P. 140E
VII/86 and Rev.1	Study Group VII	Draft Report – A method for classifying systems which yield time and frequency information from the same radio emission	S.P. 140E
VII/87 and Rev.1	Study Group VII	Proposed amendments to Draft Report H.f(VII)	
VII/88	Working Group VII–B	Draft Opinion – Studies and experiments concerned with time-signal emissions	Q. 140
VII/89	Working Group VII–B	Proposed ammendments to Draft Report H.e(VII)	

Doc.	Origin	Title	Reference
VII/90	Working Group VII–B	Proposed amendments to Tables I and II of Draft Report H.d(VII)	
VII/91	Working Groups VII–A and VII–B	Draft Report H.d(VII) – Standard-frequencies and time-signals	Q. 140
VII/92	Study Group VII	Summary record of the second meeting	
VII/93	Study Group VII	Summary record of the third meeting	
VII/94	Study Group VII	Status of texts	
VII/95	C.C.I.R. Secretariat	List of documents issued (VII/59 to VII/95)	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP VII

Doc.	Title	Final text
VII/1001	Standard-frequency and time-signal emissions	Res. 14–1
VII/1002	Avoidance of external interference with emissions of the standard-frequency service in the bands allocated to that service	Rec. 376–1
VII/1003	Standard-frequency and time-signal emissions in additional frequency bands	Rec. 375–1
VII/1004	Standard-frequency and time-signal emissions in additional frequency bands	Op. 27
VII/1005	Special monitoring campaigns by the I.F.R.B. with a view to clearing the bands allocated exclusively to the standard-frequency service	Op. 28
VII/1006	Stability and accuracy of standard-frequency and time-signals as received	Rep. 271–1
VII/1007	Single-sideband operation for the standard-frequency and time-signal service	Rep. 362
VII/1008	Intercomparisons of time scales by various methods	Rep. 363
VII/1009	Reduction of mutual interference between standard-frequency and time-signal emissions	Rep. 269–1
VII/1010	Instability of standard-frequency generators	Rep. 364
VII/1011	Studies and experiments concerned with time-signal emissions	Op. 26
VII/1012	Standard-frequency and time-signal emissions	Rec. 374–1
VII/1013	Dissemination of standard-frequencies by carrier-frequency stabilization of broadcasting emissions	S.P. 4A/VII
VII/1014	Standard-frequencies and time-signals	Rep. 267-1
VII/1015	Comparative statistics concerning the properties of UT and AT radio emissions	Rep. 365
VII/1016	A method for classifying systems which yield time and frequency information from the same radio emission	Rep. 366
VIII/1017	Frequency spectrum conservation for high precision time-signals	Rep. 270–1
VII/1018	List of documents issued (VII/1001 to VII/1018)	

RECOMMENDATIONS OF SECTION J (MONITORING OF EMISSIONS)

RECOMMENDATION 182-1

AUTOMATIC MONITORING OF OCCUPANCY OF THE RADIO-FREQUENCY SPECTRUM

(Question 9/VIII)

The C.C.I.R., (1956 – 1966)

CONSIDERING

(a) that the increasing demand of radio services requires the most efficient use of the radio-frequency spectrum;

(b) that the most efficient use of the spectrum can be arranged only when the distribution in time, magnitude and direction of the signals occupying it is known;

(c) that automatic monitoring equipment is now in use by Administrations and that further development in automatic observation is foreseen, including methods for the analysis of records;

(d) that, by the use of automatic monitoring equipment, a number of parameters can be evaluated which are of considerable value in enabling more efficient utilization of the spectrum;

UNANIMOUSLY RECOMMENDS

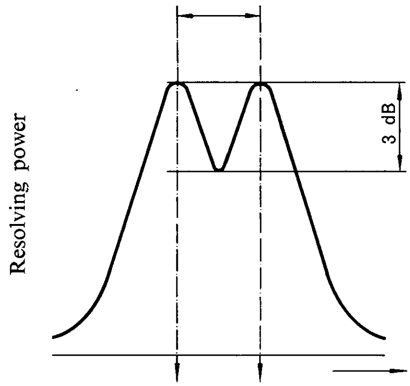
1. that, although automatic monitoring equipment will not completely replace manual observations, it is a valuable aid. Administrations should be encouraged to undertake the use and further development of such equipment;

2. that, although further study is needed to enable Administrations and frequency-planning authorities to derive the greatest benefit from the records produced, it is desirable that equipment should possess the following principal characteristics:

– total frequency range	– minimum 2 to 30 MHz; desirable 10 kHz to 30 MHz or more;
– swept frequency range	variable, typical range 20 to 1000 kHz;
– number of sweeps per hour	variable, 30 to 180;
– maximum rate of sweeping	variable; dependent on the desired frequency resolution for the band being swept and the class or classes of emission being recorded;
– sensitivity	1 μV/m or better;
– resolving power	variable; approximately 100 to 5000 Hz;
– signal characteristics recorded	– carrier frequency, – bandwidth, – field-strength, – duration of occupancy;
– size of records	paper chart 20 cm × 32 cm for twenty-four hours; calibration at intervals of 1, 10 or 100 kHz as appropriate.

Note. – Frequency resolving-power is the smallest frequency difference between two stable carriers of the same level which can be distinguished. For equipment using oscilloscopes, this power is the limit to which two stable carriers of the same level can be observed separately with a difference of 3 dB between the peak levels of the emissions and the minimum level between those peaks (see Fig.).

3. that it is desirable that the records should also contain, if possible, the following information:
   - name and location of monitoring station;
   - date and period of recording;
   - frequency band;
   - signal identification, as appropriate;
   - class of emission, as appropriate;
   - direction of signal;
   - noise level.



FIGURE

RECOMMENDATION 377-1

ACCURACY OF FREQUENCY MEASUREMENTS AT MONITORING STATIONS

(Question 1/VIII)

The C.C.I.R., (1948 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) the requirements of the Administrations, of international organizations carrying out monitoring observations and of the I.F.R.B., in respect of the frequency measurements necessary for the efficient performance of their duties;

(b) the general availability of suitable monitoring equipment for frequency measurements;

(c) that it is desirable that the errors of frequency measurement shall not exceed one-tenth of the frequency tolerances specified in Appendix 3 to the Radio Regulations, Geneva, 1959;

UNANIMOUSLY RECOMMENDS

that monitoring equipment and procedures shall be such that frequency measurements shall be made with an accuracy equal to, or better than, that specified in the following Table:

Type of measurement	Accuracy
Measurements of the frequencies of stations, except broadcasting stations, operating in the band 10 kHz to 4000 kHz	±5 parts in 10^6 (or, where this would be less than ±1 Hz, to an accuracy of ±1 Hz)
Measurements of the frequencies of broadcasting stations, operating in the band 10 kHz to 4000 kHz	±1 Hz
Measurements of the frequencies of stations, except television broadcasting stations, operating in the band 4000 kHz to 500 MHz	±1·5 parts in 10^6
Measurements of the frequencies of stations, except television broadcasting stations, operating in the band 500 MHz to 10·5 GHz	±1 part in 10^5
Measurements of the frequencies of television broadcasting stations, operating in the band 30 MHz to 1000 MHz	±100 Hz
Measurements of the frequencies of stations, operating above 10·5 GHz	±5 parts in 10^5

Note 1. – It is realized that, while the accuracies quoted above are sufficient for international monitoring, higher accuracies may be needed to meet national requirements.

Note 2. – For frequency measurements made solely to investigate occupancy of frequency channels, the permissible error for stations operating in the band 10 kHz to 30 MHz is ± 3 parts in 10^5.

Note 3. – When compared with the table of ultimate tolerances for transmitters adopted in Geneva, 1963 (Report 181-1, Table I, Column 4), it is apparent that, if and when these ultimate tolerances are made part of the Radio Regulations, the accuracies of measurement as indicated in the above Table will, in some cases, be inadequate to maintain the desired 1 to 10 ratio of measurement error to station tolerance.

RECOMMENDATION 378-1

ACCURACY OF FIELD-STRENGTH MEASUREMENTS AT MONITORING STATIONS

(Question 3/VIII)

The C.C.I.R., (1953 – 1956 – 1963 – 1966)

CONSIDERING

(a) that field-strength measurements are made at monitoring stations in the frequency range 10 kHz to 1 GHz;

(b) that accurate measurements, for use in connection with the international registration and assignment of frequencies, may be desirable;

(c) that the publication of such data from monitoring stations is also desirable;

UNANIMOUSLY RECOMMENDS

1. that, to obtain the accuracies specified in § 2, the field-strength measuring equipment at monitoring stations should be installed and operated in accordance with the Annex to this Recommendation;

2. that, except where there are limitations due to receiver noise-level, atmospheric noise or external interference, the accuracy to be expected in field-strength measurements, at values above 1 μV/m, should be:

Frequency band (MHz)	Accuracy of measurement (dB)
Below 30	± 2
30 to 1000	± 3

3. that when, because of limitations of measuring instruments, interference, signal instability or for other reasons, the accuracies shown in § 2 are not obtainable, the measurements should nevertheless receive due consideration commensurate with the accuracy indicated.

ANNEX

1. Fixed antenna installation

1.1 *Frequencies of 30 MHz and below*

It is recommended that, for frequencies of 30 MHz and below, vertical antennae shorter than one-fourth wavelength should be used, with ground systems consisting either of buried radial conductors at least twice the length of the antenna and spaced 30° or less apart, or of an equivalent ground screen.

It is necessary to ensure that no significant distortion of the field being measured is caused by obstructions, buildings, buried pipes, etc.

Vertical antennae, as described above, are recommended as standard for field-strength measurement by monitoring stations, for ionospheric signals at frequencies of 30 MHz and below for the following reasons:

1.1.1 it is generally accepted that random variations in polarization of ionospheric waves are such that the vertically polarized component is, in general, substantially equal to the horizontal component;

1.1.2 the response of a vertical antenna, shorter than 1/4 of a wavelength, is substantially independent of frequency.

1.2 *Frequencies above 30 MHz*

Antennae for field-strength measurement at frequencies above 30 MHz are recommended to conform to the following conditions:

1.2.1 The receiving antenna must have the same polarization as the transmitting antenna. For these frequencies, short monopole antennae, half-wave dipoles and high-gain antennae are appropriate.

1.2.2 It is preferable that the antennae be located at a height of 10 m above ground.

1.2.3 Consideration should be given to environmental conditions (e.g. terrain and obstructions), to minimize factors reducing accuracy.

1.3 *Antenna factor*

The error in the determination of the antenna factor should be kept within 1 dB. The antenna factor takes into account coupling or mismatch losses between the antenna and the receiver, in the parts not common to the measuring and calibrating circuits.

2. Receiver

The receiver should have high inherent stability with respect to gain, frequency, bandwidth and attenuation. Particular attention is drawn to the desirability of using voltage regulators and crystal-controlled oscillators to limit the effect of the receiver on the overall accuracy of field-strength measurements.

3. Calibration

The field-strength-measuring installation should be calibrated as required to maintain the accuracies given in § 2 of this Recommendation. A suitable method of calibration, which takes into account the requirements of § 1.3, involves comparison of the indicated signal levels observed with the measuring equipment with the actual field strength, as determined by a calibrated field-strength meter of known accuracy, of emissions from stations operating on or near the frequency on which regular field-strength measurements are to be performed. Where such measurements are made over an extended frequency range, a calibration curve may be prepared based on comparison measurements at frequent intervals over the frequency range of interest. When performing these comparisons, the monitoring-station antenna and the field-strength meter antenna should have the same polarization (e.g. both antennae adjusted for reception of vertically-polarized emissions, or both for horizontally-polarized emissions). To insure against variations in receiver gain, it is desirable to check the receiver at frequent intervals (e.g. daily) with a radio-frequency standard-signal generator of known and stable characteristics.

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RECOMMENDATION 379-1

IDENTIFICATION OF RADIO STATIONS

(Question 14/VIII)

The C.C.I.R., (1951 – 1953 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that the Radio Regulations, Geneva, 1959, Article 19, set forth requirements for transmissions of call signs and state that each radio station provided with a call sign from the international series must, unless otherwise provided, transmit this call sign during the course of its emission;

(b) that certain types of radio stations are exempted from the necessity of having an international call sign, for example, stations which are identified by other means;

(c) that, in some cases, the requirement to transmit the identifying signal by interrupting the traffic imposes difficulties;

(d) that methods for identifying certain complex types of emission have been evolved;

UNANIMOUSLY RECOMMENDS

1. that for the purpose of identification, the identifying signal should be transmitted, using:

1.1 International Morse code with classes of emission A1, A2, F1 or F2, preferably transmitted at manual speed; or

1.2 five-unit code (International Telegraph Alphabet No. 2) with classes of emission A1, A2 or F1, at the standardized speed of 50 bauds; or

1.3 speech in clear;

2. that, if the station does not desire to interrupt traffic for identification, it should superimpose the identifying signal on the traffic by using the following methods:

2.1 *Class of emission F1* (especially for high-speed or multi-channel operation): additional modulation (frequency or phase) of the carrier by the identifying signal in International Morse code;

2.2 *Single- or independent-sideband emissions:* amplitude keying of the reduced carrier or some other pilot frequency;

2.2.1 keying of the reduced carrier, with a difference in level of 5 dB, gives a satisfactory compromise between an acceptable degree of distortion of the traffic signals and the suitability for identification purposes, especially if the identifying signal is repeated;

Note. – With reduced-carrier emissions the above-mentioned method can only be applied if receivers without automatic frequency control are used.

2.2.2 keying a pilot frequency lower than the lowest traffic modulation frequency provides a satisfactory means of identification for suppressed carrier emissions;

2.3 *Facsimile transmissions employing class of emission A4*: amplitude-modulation, at a frequency below the lowest used for the facsimile modulation. When single-sideband transmission is used, amplitude keying, as in § 2.2 may be used;

3. that, to avoid additional complexity in the equipment and operation of transmitting stations, every reasonable effort should be made to provide monitoring stations with equipment suitable for the reception of identifying signals of all stations;

4. that Administrations should be encouraged to cooperate directly with one another in carrying out tests of identification methods. Administrations are also invited to inform the I.F.R.B., in advance of such tests, of new methods of identification to facilitate cooperative observations and also to afford other Administrations the opportunity to become acquainted with such methods for the identification of radio stations.

RECOMMENDATION 442

EXPEDITIOUS METHOD OF DETERMINING FIELD STRENGTH AT MONITORING STATIONS

(Question 4/VIII)

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

CONSIDERING

(a) that stations participating in the international monitoring system, as a part of their normal work, need to make expeditious measurements of the field strength of harmful interference;

(b) that a lower degree of accuracy than that specified in Recommendation 378-1 can be accepted, in the frequency band from 12 kHz to 30 MHz,

UNANIMOUSLY RECOMMENDS

that, for the expeditious measurement of field strength at monitoring stations, a method either of substitution or of overall calibration of the measurement system, providing an accuracy better than $\pm$ 6 dB be adopted from among the methods specified in Report 368.

RECOMMENDATION 443

BANDWIDTH MEASUREMENTS AT MONITORING STATIONS

(Question 5/VIII)

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

CONSIDERING

(a) the need for the measurement of bandwidths of emissions at monitoring stations to promote efficient use of the radio-frequency spectrum;

(b) that the equipment for measuring bandwidths at transmitting stations does not produce accurate measurements when employed at monitoring stations;

(c) the slow progress of studies concerning the best equipment and methods for bandwidth measurements;

(d) the need for a uniform estimate of bandwidths at monitoring stations, to enable the I.F.R.B. to compare the results obtained by different monitoring stations;

(e) Report 275-1;

UNANIMOUSLY RECOMMENDS

that, until a method of measurement in monitoring stations can be devised that will conform to the definition in No. 90 of the Radio Regulations, Geneva, 1959, the monitoring stations should adopt, provisionally, as an estimation of the bandwidth, a method consisting of measuring the bandwidth at 6 dB and at 26 dB.

Note 1. – An " *x* dB " bandwidth should be regarded as that band outside of which discrete components of the spectrum of the emission are attenuated to an amplitude *x* dB or more below the level of the peak value of the emission, as indicated by a spectrum analyser (see Report 324)

Note 2. – It is recognized that in measuring bandwidth of emissions, the results obtained by this method may have no simple relationship to the " occupied bandwidth " as defined in No. 90 of the Radio Regulations, Geneva, 1959.

REPORTS OF SECTION J (MONITORING OF EMISSIONS)

REPORT 272-1 *

FREQUENCY MEASUREMENTS AT MONITORING STATIONS

(Question 1/VIII)

(1956 – 1959 – 1963 – 1966)

Question 1/VIII seeks information on the desirable ratio of the error of frequency measurement to the permissible tolerances of emission and the accuracy required for frequencies extending up to, in certain cases, at least 10·5 GHz.

Information on equipment, accuracy of measurement and methods, is contained in Docs. VIII/1 (U.S.A.), VIII/13 (Japan), VIII/18 (Japan), VIII/27 (United Kingdom) and VIII/28 (United Kingdom), Washington, 1962. The information available at present may be summarized as follows.

1. General

1.1 When an individual measurement of a radio station is made, its accuracy can be estimated from a knowledge of all of the factors (except perhaps that of Doppler effect), which produced the error. The sources of error which should be known to the measurer, are: the maximum error in the frequency standard of reference; the maximum instability error of the transfer oscillator and the error of setting that oscillator to zero-beat with the signal. Inasmuch as the direction of errors, other than that of the reference standard, will not usually be known, the errors of measurement should be provisionally estimated, until an answer to Study Programme 1A/VIII is obtained, as if they were all in the same direction after allowing for any known error of the reference standard.

1.2 It is considered, that a conservative ratio of error to tolerance as applied to the majority of frequency measurements, is to be preferred over a ratio difficult to obtain. With a conservative ratio, the measuring equipment may be operated well within its capabilities with a greater degree of assurance that all measurements meet the desired minimum accuracy.

1.3 The ratio of 1 to 10 between the error of measurement and the tolerance appears to be a reasonable criterion to be retained at least until such time as conclusions are reached in the work of Study Programme 1A/VIII. In this study, it may be desirable to adopt a statistical method of arriving at the accuracy of measurement of an unknown frequency (see Doc. VIII/18 (Japan), Washington, 1962).

2. Accuracy of measurement

With regard to § 1 of Question 1/VIII, on the accuracy of frequency measurements which can be accomplished at monitoring stations, the following statements may be made:

2.1 The accuracy of the secondary standard of a frequency measurement installation is determined by calibration. A stability of $\pm$ 1 part in 10^9 or better can be achieved with currently available standards, including those designed for mobile use. The accuracy may not exceed $\pm$ 1 part in 10^7 when using standard-frequency transmissions received over a sky-wave path. However, by selecting a time of day for the comparison during which sky-wave propagation conditions are most stable (usually around noon of the path mid-point), and by continuing the comparison over a period of several minutes, accuracy of a few parts in 10^8 is readily

* This Report was adopted unanimously.

achievable. Where ground-wave HF or usable VLF/LF emissions from standard-frequency stations are available, the secondary standard accuracy may be maintained to better than $\pm$ 1 part in 10^8.

Where greater accuracy is required, either for fixed or mobile installations, use may be made of an atomic frequency standard. Atomic standards weighing less than 20 kg, requiring 50 W or less of operating power, and having an accuracy of $\pm$ 1 part in 10^9 or better, are available.

2.2 The methods of measurement usually employed result in the determination of the instantaneous frequency as received. Therefore, when measuring distant stations, due regard must be given to frequency shifts caused by varying propagation conditions (e.g. Doppler effect). Errors, due to the use of a stable transfer oscillator, can be reduced to a negligible amount by the use of an oscilloscope for zero-beat adjustment. In anticipation of the extensive use of VLF/LF standard-frequency emissions, the desirability of future reduction of the error to an appropriate smaller value should be kept in mind. This is of particular importance in connection with services in which a 1 to 10 ratio of measurement error to station tolerance cannot be achieved with a frequency standard having an accuracy of only $\pm$ 1 part in 10^7.

2.3 When compared with the table of ultimate tolerances for transmitters adopted by the C.C.I.R. at Geneva in 1963 (Report 181-1, Vol. I, Table I, Column 4), it is apparent that, if and when these ultimate tolerances are made part of the Radio Regulations, the accuracies of measurement as indicated in the following Table will, in some cases, be inadequate to maintain the desired 1 to 10 ratio of measurement error to station tolerance.

TABLE I

Accuracy of measurement attainable under optimum conditions at fixed and mobile monitoring stations (n is the integer equal to, or immediately above, one thirtieth of the measured frequency in MHz

Class of emission	Fixed stations	Mobile stations
A0, A3, A3B	$\pm 2{\cdot}5 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz	$\pm 4 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz
F1, A1	$\pm 2{\cdot}5 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz $\pm 2{\cdot}5$ Hz	$\pm 4 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz $\pm 2{\cdot}5$ Hz
F1, MUX	$\pm 2{\cdot}5 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz ± 10 Hz	$\pm 4 \times 10^{-8} \pm 0{\cdot}5\ n$ Hz ± 10 Hz
F3 using discriminating equipment	$\pm 2{\cdot}5 \times 10^{-8} \pm 100$ Hz	$\pm 4 \times 10^{-8} \pm 100$ Hz

2.4 For emissions with a discrete component at the assigned frequency, which can be identified, the accuracy is practically the same as for unmodulated emissions. For emissions having discrete components which can be identified at other than the assigned frequency, the accuracy is further limited by the accuracy with which the displacement is known.

2.5 Under conditions of fading, and where the measurement is made using a pattern on the screen of an oscilloscope, the measurement is performed only when there is sufficient signal strength, e.g. A1 stations are measured only during on-keyed conditions and not during a field-strength minimum period. Under these conditions the accuracies listed in Table I can be obtained.

2.6 Under conditions of interference between two amplitude-modulated stations, the frequency of the weaker station can still be measured with the accuracy indicated in Table I, if the carriers of the wanted and unwanted stations are spaced by at least 40 Hz. With a field-strength ratio between the wanted and the unwanted stations of 1 to 1, good measurements may be made with the accuracy indicated in Table I, when the carriers are only spaced by 12 Hz. For a field-strength ratio of 2 to 1, the minimum frequency spacing at which good results are obtained is 2 Hz. These high accuracies of measurement are made possible, even under conditions of interference by other stations, by visual observation of the Lissajous patterns produced on the oscilloscope screen by combining the heterodyne beat between the received signal and the comparison frequency and a fixed standard-frequency of 1000 Hz. By receiving mutually interfering stations on a direction-finding equipment, their ratio of signal strengths at the receiver input can be improved, thus making possible measurements with the accuracies shown in Table I at smaller carrier spacings.

2.7 Two interfering frequency-modulated stations can be measured for unfavourable field-strength ratios when the frequency separation between their carriers is at least 2 to 3 kHz. The measurements are taken during periods of no modulation by heterodyning the wanted carrier with the comparison frequency and observing the results on a panoramic display screen. The accuracy will then be within ± 500 Hz. Here too, by employing a direction-finding technique, the received signal strength of the unwanted station may be sufficiently attenuated to attain the accuracies indicated in Table I.

2.8 Measurements of carrier instability can be made, either as a series of measurements of instantaneous frequencies employing the oscilloscope method or, with rapid variations of the carrier frequency, the centre frequency can be determined by means of a discriminator equipment, or a panoramic adaptor, resulting in an accuracy of measurement of the extreme frequencies of about ± 50 Hz.

2.9 Keyed carriers can be measured by the oscilloscope method with the accuracies listed in Table I.

2.10 For suppressed carriers, individual frequencies of the types listed under §§ 2.5, 2.6, 2.7, 2.8 and 2.9, which are contained in the emission spectrum, can be measured with the accuracies listed in those paragraphs. For a carrier not completely suppressed, the measurement can be made with the accuracy indicated in § 2.6.

3. Equipment and methods

3.1 With regard to measurements above 50 MHz, the frequency measuring equipment of the individual countries differs so much that it is only possible to comment generally upon them. Administrations usually prefer to make measurements with nearly the same equipment as that which they use for frequency measurements below 50 MHz. The extension to a higher frequency range is effected by the use of harmonics of either a secondary standard or a stable oscillator or by the use of a frequency synthesis method providing a single tunable frequency. All equipment uses direct reading dials in conjunction either with electronic counters or with visual indicators such as pointer instruments or oscilloscopes.

3.2 With regard to preferred equipment and methods for the measurement of frequency in frequency-modulated emissions, the carrier frequency may be measured by any of the usual methods during intervals of no modulation. With modulation, it is common practice to measure the average frequency by means of a frequency counter. In many types of programme material, the peak excursions of an FM carrier in the positive and negative directions may be considerably different while, at the same time, the average frequency will remain constant. This non-symmetrical programme material may result, for example, from certain combinations of a fundamental tone and its various harmonics. Then the average over a period of several cycles at the lowest modulating frequency will approximate the unmodulated carrier frequency. Therefore, the averaging technique is valid under all normal conditions, provided the period of the frequency count is long compared with one cycle at the lowest modulating frequency. Instabilities in the transmitter may, of course, result in a shift in the average frequency of the carrier, so that the frequency indicated by the counter would differ somewhat from the unmodulated carrier frequency.

3.3 With the availability of portable battery-operated frequency standards, stable to $\pm$ 1 part in 10^8 per day, UHF television stations operating with $\pm$ 1000 Hz tolerance may be measured to the recommended accuracy. A daily check against standard-frequency emissions at the optimum time of the day as regards propagation stability will suffice to achieve an accuracy of the standard considerably better than the $\pm$ 1 part in 10^7 that is required for these measurements. For greater accuracy, such as might be involved where precision offset techniques are used, very accurate measurements could be achieved by use of a portable atomic standard. VLF standard-frequency emissions also provide a means of improving the accuracy at mobile as well as fixed monitoring stations. Battery-operated equipment, comprising a selective VLF receiver and phase or time comparison circuitry, may be used to permit accurate calibration of the frequency standard. Such comparison equipment, in combination with a battery-operated frequency standard and a transistorized electronic counter, provides a convenient means of achieving a high degree of accuracy even under mobile conditions.

The importance and potential usefulness of statistical analyses of frequency measurement data is described in Doc. VIII/18, Washington, 1962. This document also suggests a method of arriving at the accuracy of a measurement of an unknown frequency by obtaining the standard deviation of a number of measurements made of a known frequency.

In Doc. VIII/27, Washington, 1962, the overall accuracy of frequency measurements, attainable in the range 1 to 10 GHz, was indicated using a typical spectrum analyzer with the following characteristics: varies from 8 kHz (for a 250 kHz sweep), to 100 kHz (for a 70 MHz sweep), equivalent to $\pm$ 8 parts in 10^6 and $\pm$ 1 part in 10^4 respectively at a frequency of 1 GHz. Thus, an accuracy of $\pm$ 1 part in 10^5 would appear possible, in practice, for the range 1–10 GHz for the condition where the emission contains a known discrete component whose position relative to the unmodulated carrier frequency is accurately known. Where it is possible to obtain a beat frequency output, the accuracy of measurement may be increased to $\pm$ 1 part in 10^6 or even better.

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REPORT 273-1 *

FIELD-STRENGTH MEASUREMENTS AT MONITORING STATIONS

(Question 3/VIII)

(1959 – 1963 – 1966)

Question 3/VIII seeks information on various aspects of the measurement of field-strength at monitoring stations, including the preferred methods and equipment for making such measurements in connection with propagation studies, measurement problems peculiar to certain special types of emissions (e.g., interrupted and reduced carriers and television signals), measurements in the presence of noise and interference; together with determination

* This Report was adopted unanimously.

of the extent to which measurements at a distance can give useful information relative to harmonic levels at the transmitter itself; and a determination of the most useful programme which can be carried out in fulfilling the needs of the I.F.R.B., other Study Groups of the C.C.I.R. and other bodies.

The contributions (Docs. VIII/6, VIII/8, VIII/16, VIII/20 and VIII/22, Los Angeles, 1959, together with Docs. VIII/6 and VIII/25, Washington, 1962), are summarized herein. In considering Question 3/VIII, reference should also be made to Report 227 which contains useful information.

1. Preferred methods and equipment

1.1 *Methods of measurement*

A number of methods of making field-strength measurements at monitoring stations are described, including:

- continuous recording over periods of several hours;
- continual sampling at short intervals (for example, for 5 s every two minutes) (see § 1.2.6 for details);
- sampling at longer intervals (for example, for 10 min each 90 min).

In some instances, especially where a ground wave is being observed, a single short period of measurement may suffice, depending upon the purpose for which the measurement is required.

In certain cases, e.g. measurements for the purpose of HF propagation studies, one may require information concerning the overall propagation conditions over a band of frequencies. The present method of automatic monitoring of spectrum occupancy will yield only a very rough impression of the propagation conditions, since it does not discriminate between the various path directions and cannot make allowance for the difference in distances between the transmitting stations and the location of the receiver. Therefore, it may be expedient to make short records lasting about 10 min, over the entire high-frequency band at intervals of about 90 min, of stations known to be working for 24 hours a day, so chosen that the ranges of frequencies and distances of interest are well represented.

Time constants of the detector circuit for measuring non-interrupted carrier emissions are selected according to the results desired, with values of the order of a few seconds on both the charge and discharge cycles commonly used for average values. For quasi-peak values, a short charge time constant with a much longer discharge time constant is needed.

For the measurement of the quasi-peak values of field-strength of an emission with interrupted carrier, a circuit may be employed with time-constants of 1 ms build-up time and 600 ms decay time. When this method is not suitable (e.g. keyed pulses), because of too long a build-up time, the measurement may be made by the substitution method using a cathode-ray oscilloscope.

1.2 *Measuring and recording equipment*

1.2.1 *General*

A typical field-strength recording installation consists of a suitable antenna, a sensitive receiver with a bandwidth appropriate to the emission to be recorded and including provisions for converting the received signal into a corresponding direct current for operation of an associated recording device, and a standard signal generator for use in calibrating the receiver in terms of radio-frequency voltage input levels.

To ensure minimum frequency drift, the conversion oscillators in the receivers are, wherever possible, controlled by quartz crystals. Stabilization of the alternating current line voltage is provided by primary voltage regulators. Further protection against fluctuation is obtained by stabilization of the d.c. voltages in the receiver. Minimization of changes in receiver gain is accomplished by careful design of receiver circuits, by the aforementioned voltage stabilization and by operating the equipment at an essentially constant temperature.

1.2.2 *Antennae*

For measurements in the low, medium and high frequency bands, a stub antenna with impedance matching transformers or a wideband stub antenna with constant feed impedance may be used. In some particular cases, however, a directional antenna designed for a single frequency or a narrow band of frequencies may be preferred. Field-strength measurements on VHF and UHF bands are best made by means of a wideband dipole or a special directional antenna (e.g. a dipole installed in a corner-reflector or parabolic reflector). In the upper part of the UHF band and in the SHF band successful use has been made of log-periodic antennae, either with or without parabolic reflectors, so installed that near optimum results, with low standing-wave ratios, are achieved over a frequency range of 2/1 or greater.

1.2.3 *Recorders*

Although ink-line, strip-chart recorders continue in common use, direct recording of the statistical distribution of the variations in field-strength by automatic distribution counters is also being done. Another method, reported by the Federal Republic of Germany, makes use of magnetic tape equipment. In this method, the variations of the d.c. voltage on the a.v.c. line, representative of the field-strength, are transformed to audio frequencies (50 to 300 Hz), by means of an oscillator controlled by a reactance valve and used to modulate the amplitude of a low frequency carrier (about 5 kHz).

1.2.4 *The calibrating equipment*

The calibration process involves two phases:

- determination of the effective height of the receiving antenna, taking into account losses in the connecting transmission line;
- daily, or more frequent, receiver calibration, to eliminate possible errors due to progressive changes in sensitivity.

Doc. VIII/6, Los Angeles, 1959, suggests that it is good practice to calibrate initially the field-strength meters, for use on frequencies below about 30 MHz, on a loop antenna. The loop is placed at a small defined distance from a Lecher line which is terminated with a resistance equal to its surge impedance, which can be coupled to a radio-frequency source. If the current flowing in the Lecher line is known, the field intersecting the loop can be computed.

To determine the effective height of an antenna, the input signal to the receiver is compared with the indication of a calibrated field-strength meter.

1.2.5 *Frequency ranges involved*

Although field-strength measurements have been made over almost the entire usable spectrum, most of the activity up to the present has been concentrated at frequencies below 1 GHz. As greater use is made of the microwave frequencies for space-to-ground transmissions, it seems likely that there will be increased activity in field-strength measurements in these higher frequency ranges. Examples of measurement programmes for field-strength which are now under way, or have been concluded in recent years, are:

- in the 540 to 1600 kHz broadcast band, continuous recordings have been made during the past two sunspot cycles;

- VHF and UHF field-strength measurements (FM and television broadcast stations), have been in progress since 1946 at various locations over paths having lengths from 60 to 1000 km (37 to 620 miles);

- certain monitoring stations in the U.S.A. are determining the field-strength of experimental UHF television stations located in aircraft. These experiments are done in connection with extending the service area;

- a monitoring station in the United Kingdom is making regular field-strength recordings of incoming radiotelegraph signals from Accra, Bombay and Colombo, as a partial contribution to Resolution 7–1 (Sky-wave field-strength and transmission loss at frequencies between the approximate limits of 1·5 and 40 MHz;

- the station in the United Kingdom has also made long-term field-strength measurements of ten distant VHF (metric) and UFH (decimetric) transmitters and two distant ionospheric-scatter transmitters and the data obtained have been summarized and submitted to the C.C.I.R. (Doc. VIII/25, Los Angeles, 1959).

1.2.6 *Analysis of the records*

Recordings made in the 540 to 1600 kHz broadcast band are analysed, to obtain hourly median values of field-strength and from these data monthly median values may be obtained. Particular attention is given to the second hour after sunset for the mid-point of the path between transmitter and receiver. Values for other hours and for levels other than the median may be obtained in a similar manner.

In the HF, VHF and UHF bands, it is often desirable to determine the upper decile (F_{10}), the median (F_{50}) and the lower decile (F_{90}) values. The median value, in dB relative to 1µV/m, is a desirable form of presentation of measurements at discrete frequencies for propagation studies.

A system of analysis, which eliminates much of the human effort, is based upon a method of recording periodic samples of signal strength, using regular equipment with simple modification rather than a continuous registration of signal levels. A time switch operated by a synchronous motor is provided in each recorder so that a contact is closed once every two minutes for a duration of about five seconds. This contact is inserted in an appropriate circuit in the receiver, where it will cause the recording instrument to respond by drawing an inked line with each operation of the switch. The recorder chart will then show a series of transverse lines. When operated at the usual speed of about 75 mm (three inches) per hour, the paper will show 4 lines per cm (10 lines per inch), each having an amplitude with a known relationship to field-strength. It has been found that 30 samples per hour will yield an accuracy adequate for most applications. After the recording have been made, the charts are analysed on equipment specially constructed for this purpose. This equipment may consist of a photoelectric cell arrangement for counting the hourly number of samples with amplitudes exceeding a pre-set level, while the chart paper moves through an appropriate optical system. Hourly numbers of samples at each level are counted automatically and printed by means of an electrical counter and a sequential count printer. These numbers may be directly converted to equivalent percentages of time, for all signals exceeding given levels. The data are thus available in hourly values, from which monthly and yearly distribution curves may be plotted, showing daily and seasonal variations of field-strength at any percentile levels.

2. Preferred equipment and methods of measurement in the presence of noise and interference

No particular problems are presented in measuring the field-strength of emissions with interrupted carrier and of television video signals in the presence of noise and interference, as long as the noise and interference peak levels are below the level of the wanted signal, since the quasi-peak indicating device will respond to the highest level present. However, in the case where the peaks of noise and interference are greater in intensity than the wanted emission, other techniques must be used. In some instances, reduction of the receiver bandwidth may be effective in eliminating unwanted emissions. The effect of high noise peaks of short duration can possibly be avoided, by increasing the charge time-constant of the detector sufficiently to minimize receiver response to the noise without appreciable reduction in the indicated level of the wanted signal. The efficacy of such expedients would, of course, depend on circumstances and very likely would not be valid under conditions of heavy fading. Doc. VIII/16, Los Angeles, 1959, describes a method used in Japan, for the measurement of emissions in the presence of adjacent-channel interference, using a panoramic unit attached to the equipment, so that an interfering emission may be separated from the wanted signal and the field-strength represented by the deflection of the oscilloscope trace caused by the interrupted carrier under study, may be determined by comparison with a signal from the equipment used for calibration purposes.

3. Determination at a distance of relative radiation levels of fundamental and harmonic frequencies of an emission

It would appear that this matter should be considered in two parts:

- conditions where both the fundamental and the harmonic emissions to be measured arrive at the measuring point over a ground-wave or line-of-sight path;
- where either the fundamental or the harmonic emission, or both, arrive at the measuring site over a sky-wave path.

The situation as regards these two modes of propagation will be considered separately.

3.1 *Measurement of radiation levels under conditions of ground-wave or line-of-sight propagation*

Study Group V, in response to a request for assistance on this matter, has referred Study Group VIII to Report 227. This Report contains detailed information on making and evaluating such measurements, taking into account instrument errors, differing attenuation rates at different frequencies and other variables.

3.2 *Measurements of radiation levels where sky-wave paths are involved*

Study Group I has considered this matter, as evidenced by Recommendation 329-1 and Study Programme 7A/I. Likewise, Study Group VI, in Reports 252-1 and 257-1 reviews progress which has been made in determining the best method of calculating the field-strength at a distance from the transmitter (ionospheric propagation), and describes plans for further study of this matter.

It is expected that the results of the further deliberations of Study Groups I and VI will be of benefit to the international monitoring system in its efforts to minimize interference from spurious emissions. Pending the outcome of these deliberations, it would be highly desirable for stations in the international monitoring system to have certain guide-lines which might be followed in obtaining evidence of possible excessive radiation at the harmonic frequency. While such evidence would not be conclusive, it might serve as an indication that close-in measurements should be made to verify the existence of harmonics at excessive levels. Appendix 4 of the Radio Regulations, Geneva, 1959, gives power limitations on spurious emissions as measured at the antenna transmission line input. Although these emissions may readily be measured at that point, there is no simple means of converting the spurious power limitations given in Appendix 4 to equivalent field-strength at a distance. Since it is the actual radiated spurious field-strength rather than the power into the antenna which is of primary concern as an interference source, it might be well to consider establishment of a limitation on spurious emissions, in terms of the maximum unattenuated field-strength at about 1600 m (1 mile). Having once established such a limit, the maximum allowable inverse-distance field could readily be determined. Since the attenuation would actually increase more rapidly than inversely with the distance, the measured value of the spurious emission would be a conservative index of the actual radiated field, especially if the condition continues over a period of several days. This limitation would be in addition to, rather than a substitute for, the limitations on spurious power input to the antenna transmission line specified in Appendix 4. Admittedly, the results could not be compared directly with measurements made at the transmitter. However, it would appear that such standards might be of help to monitoring personnel in bringing about a reduction of interference due to harmonic radiation.

4. Additional propagation studies that are desirable

Resolution 7–1 points out the need for experimental data in the frequency range from 1·5 to 40 MHz for paths of different lengths and directions and requests that Administrations and Members of the C.C.I.R. render assistance to Study Group VI on this matter.

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REPORT 275-1 *

BANDWIDTH MEASUREMENT AT MONITORING STATIONS

(Question 5/VIII)

(1953 – 1956 – 1959 – 1963 – 1966)

1. General discussion of measurement techniques, considering the definition of occupied bandwidth – No. 90 of the Radio Regulations, Geneva, 1959

1.1 *Measurement of power ratios*

The present definition of occupied bandwidth suggests the principle described in Recommendation 327–1, § 1.2 of measuring the ratio of the total power to the parts remaining outside of the bandwidth being measured. It would be necessary to locate the upper and lower edges of the band, by totalling the power in the out-of-band components on the high

* This Report was adopted unanimously.

side until the 0·5% value is obtained and then repeating this procedure for out-of-band components below the band, starting in each case sufficiently far from the centre frequency so that no appreciable energy is omitted from measurement.

1.2 *Limitations in the accuracy of bandwidth measurements made at a distance from the transmitter*

Although a determination of occupied bandwidth of an emission, by the method of measuring total power and out-of-band power, can be accomplished when the measurements are made near the transmitter, this method is not generally applicable to measurements at a distance from the transmitter where the presence of interfering emissions or noise tend to mask the out-of-band signal components of interest. This is particularly true in the crowded MF (band 6) and HF (band 7) portions of the spectrum, regions of primary interest to international monitoring stations.

In spite of the very definite limitations which observations at a distance place upon the accuracy of measurements of occupied bandwidth, approximate determinations have been found of value when monitoring the spectrum for enforcement of bandwidth limitations. However, these non-precise measurements made at a distance, which are subject to inaccuracies for the reasons previously enumerated, should be considered as advisory only. Where greater accuracy is required, measurements at the transmitter may be desirable.

1.3 *Bandwidth measuring method which appears to be practicable for use at international monitoring stations*

It is the practice of some Administrations, in evaluating spectrum occupancy of an emission from a distant transmitter, to use the method described in Recommendation 327–1, § 1.1. In using this method, the occupied bandwidth is considered to include discrete components attenuated less than 26 dB below the peak level of the emissions. This procedure admittedly will not give a precise measurement of occupied bandwidth in terms of the definition in the Radio Regulations, Geneva, 1959. For example, it is possible that a particular emission will have numerous low-level components on either side of the main emission such, that their sum on each side would be equal to much more than 0·5% of the total mean power while having none of these discrete components exceeding the 26 dB level. In such a case, the occupied bandwidth, as determined at the transmitter by measuring power ratios, would presumably be somewhat greater than when measured at a distance by the method described in Recommendation 327–1, § 1.1.

2. Representative bandwidth measuring equipment

2.1 A spectrum analyser, of the type described in Recommendation 327–1, § 1.1, is suitable for use at monitoring stations. With this equipment, the emission spectrum is analysed by passing each component successively through a narrow-band filter of fixed frequency, by heterodyning the signal with an external frequency, varied either automatically or manually.

For the measurement of narrow-band emissions, a spectrum analyser having a high degree of resolution is desirable, so that an accurate display of the emission spectral distribution may be obtained. A typical instrument has a maximum resolution of 10 Hz and provides a swept frequency range adjustable from 1 kHz to 100 kHz, together with a sweep rate adjustable from 1 to 30 sweeps per second.

For the analysis of wide-band emissions, spectrum analysers are available which incorporate a complete receiver as well as those designed for use with general purpose receivers. A typical instrument covers a frequency range from 10 MHz to 44 GHz with a sweep width continuously variable from 200 kHz or less to as much as 70 MHz (at the higher frequencies). The sweep rate is adjustable from 1 to 60 sweeps per second.

A major shortcoming of spectrum analysers, which use a single filter to sweep the entire band under surveillance, is the incompatibility between high resolution and rapid sweep rates, especially where a band of considerable width must be studied. A fast sweep rate is necessary to obtain a representative display of transient components. However, as the sweep rate is increased, the resolution becomes poorer so that significant components of the emission will not be displayed accurately. A number of systems have been devised to minimize the sweep-rate versus resolution limitations. One method involves the division of the band to be observed into as many as eighteen sub-bands, each of which is individually swept. The eighteen outputs are then displayed one at a time on a single cathode-ray tube or simultaneously on separate tubes.

2.2 Doc. VIII/76, 1963–1966, describes two methods of estimating the occupied bandwidth in terms of the power distribution of the emission. The first of the two methods is designed primarily for the HF portion of the spectrum, while the second is reported to be useful for comparatively broadband emissions in the VHF bands.

2.3 An energy spectrum recorder is described in Doc. VIII/13, Los Angeles, 1959. This device makes a chart record of spectrum occupancy in terms of available power from a standard antenna.

2.4 A device for measuring frequency shift, especially in questions concerning the monitoring of complicated emissions and those types of emissions using a synchronous high speed multichannel system, is described in Doc. VIII/29, Washington, 1962. This device permits simultaneous measurements of frequency shift of multiplex channels as well as a visual check on the frequency shift signals.

3. A somewhat different approach to the measurement of bandwidth is described as follows (see Doc. VIII/10 (Federal Republic of Germany), Los Angeles, 1959):

Endeavours have been made to determine the bandwidth occupied by an emission, by way of the signal shape instead of by analysing the spectrum. Such experiments have been made for class of emission A1 only, starting from the fact that the bandwidth occupied is a function of the shortest build-up (and decay) time of the emitted signals (see Recommendation 328-1, § 2.1.3).

As regards the effect of fading, a comparison between 60 single measurements of A1 emissions taken at the transmitter and in the far field (up to 425 km), resulted in a maximum deviation of 16%. The average value of the deviations amounted to 4·8%. The differences in the results of the measurements at the transmitter and those taken far away may be explained by the deformation due to the fading effects of the signals. Measurements made under extreme fading conditions will not yield satisfactory results.

The effect of interference was investigated by superimposing a received non-fading A1 signal with a simulated interference signal of variable frequency generated locally. It was found that the wanted signals could still be evaluated with a signal-to-interference ratio as low as 35 dB. With signal-to-interference ratios lower than 35 dB, evaluation was no longer possible, because the 10% value of the wanted signal could not then be recognized.

4. Spectrum analysers may also be valuable in the recognition and classification of emissions, particularly complex emissions. Many types of emission have certain peculiar combinations of characteristics which, when viewed on a spectrum analyser by a trained observer, may provide valuable information leading to the recognition of the emission. Photographs of spectrum analyser displays of known emissions may be kept available to the monitoring observer for reference and for comparison with questionable emissions.

Spectrum analysers have also been used to advantage in connection with frequency measurements in the presence of interference, where matching of the frequency of the measuring equipment against the unknown frequency by aural methods is difficult. By observing the two signals on the spectrum analyser, the frequency of the measuring equipment may be adjusted to that of the unknown carrier or to other discrete components in the signal.

5. Although the estimations of the bandwidths, in terms of discrete components attenuated less than 6 dB and less than 26 dB below the peak level of the emission, may have no direct relationship with the " occupied bandwidth " as defined in No. 90 of the Radio Regulations, Geneva, 1959, such estimates can be of considerable value in detecting emissions occupying excessive bandwidths, and which may cause interference. The use of a standard method by all monitoring stations in reporting estimates of bandwidth to the I.F.R.B. should also assist the I.F.R.B in evaluating reports of different monitoring stations (see Report 324).

6. Additional information concerning measurement of bandwidth may be found in Recommendation 327-1.

7. Conclusions

To explore fully the possible accuracy of observations at monitoring stations in estimating bandwidth, studies will be required to compare such estimates with measurements performed in conformance to the definition of " occupied bandwidth " in No. 90 of the Radio Regulations. Such comparisons should include observations on various classes of emission under good reception conditions and in the presence of interference. Likewise comparison data on any new methods of estimating or measuring bandwidth, which may be reported by Administrations, will also be helpful to Study Group VIII in evaluating such methods.

REPORT 276-1 *

MONITORING OF RADIO EMISSIONS FROM SPACECRAFT AT FIXED MONITORING STATIONS

(Question 6/VIII)

(1963 - 1966)

Question 6/VIII seeks information concerning methods and equipment desirable for measurement at fixed monitoring stations of emissions from spacecraft and practical means of identification by monitoring stations of emissions from specific spacecraft.

Information concerning these matters is contained in Docs. VIII/3 (U.S.A.) and VIII/15 (Japan), Washington, 1962. The information in these documents may be summarized as follows:

1. Techniques of measurement

1.1 *General*

The main factors influencing the necessity for different techniques of monitoring observation and measurement of emissions from spacecraft as contrasted with observations and measurements of emission originating from fixed or mobile radio stations on or near the earth are, with reference to spacecraft:

- the difference between received and transmitted frequency, and the varying nature of the received frequency, caused by the Doppler effect;
- the generally weaker field-strength at the earth receiving point, due to distance and low transmitter power;
- relatively short time that a signal from a near-earth orbiting satellite is receivable at a fixed monitoring point.

* This Report was adopted unanimously.

Administrations launching spacecraft will, of necessity, continue to provide for the required accurate tracking and telemetry reception to meet their special needs. However, monitoring stations responsible for the enforcement of domestic laws and regulations and engaging in international monitoring, pursuant to Article 13 of the Radio Regulations, Geneva, 1959, will participate in space monitoring as a natural and necessary extension of their regular monitoring facilities, techniques and operations.

1.2 *Frequency measurements*

When there is a relative velocity between the spacecraft and the monitoring station, a difference of frequency proportional to the relative velocity arises between the transmitted and received signals owing to Doppler-shift effect. The apparent frequency of the transmitter in the case of an active satellite, as measured by a fixed monitoring station, is higher than the source frequency when the satellite is approaching the monitoring station and lower when it is receding. A measurement gives the source frequency only at the instant when the relative velocity between the source and the monitoring station is zero.

To determine the source frequency and the extent of Doppler shift, the basic requirement is a rapid frequency-measuring technique and a means of accurately timing each measurement. If frequency measurements are taken every few seconds and plotted against time, a curve is obtained from which the frequency at the point where the rate of change is greatest can be estimated with reasonably good accuracy, possibly to within $\pm$ 1 part in 10^6.

Doc. VIII/15, Washington, 1962, describes a frequency measuring method which uses a discriminator, the object of which is to represent on a cathode-ray oscilloscope the waveform obtained by mixing the receiver output with a low-frequency saw-tooth wave (e.g. 25 or 50 Hz) from a separate source. The discriminator is used to determine the transmitted frequency by measuring the constantly changing frequency of the Doppler shift. When the figure remains stationary on the oscilloscope, the receiver output frequency is an exact multiple of the standard low-frequency. From the value of this exact multiple and the local oscillator frequency in the receiver, the exact frequency can be determined. By measuring the frequency each time the figure on the oscilloscope becomes stationary and plotting this against time, the curve of the Doppler shift may be drawn.

1.3 *Bandwidth measurements*

The apparent bandwidth of a near-earth satellite, transmitted as measured at a fixed monitoring station, varies because of the Doppler-shift effect in the same manner as described for the carrier frequency. Although not of practical significance at present from an interference standpoint, it should be realized that the frequency shift is slightly greater for signal components near the upper edge of the spectrum of the emission than for those near the lower edge. This difference could amount to hundreds of cycles per second for the wide bandwidths proposed for some of the future spacecraft transmissions, on frequencies above 1000 MHz. This effect causes the apparent bandwidth, as observed at the fixed monitoring point, to vary slightly. However, it is doubtful that the currently available spectrum analyzers have sufficient resolution to detect it when the entire signal is being observed, under operating conditions of weak signal and relatively high background noise.

1.4 *Measurements of power flux density*

For determination of power flux density at the surface of the earth of emissions from spacecraft, two methods are under consideration (see Nos. 470 N to 470 U of the Radio Regulations as approved by the Extraordinary Administrative Radio Conference, Geneva, 1963):

- by measurement, using specialized equipment;
- by calculation, based upon measurement of field strength converted to power flux-density as follows:

$$f = 20 \log_{10} e - 25{\cdot}77$$

where f = total power flux-density in dB above 1 W/m^2,

e = field strength in V/m.

2. Equipment and facility requirements

2.1 *General*

In general, as in more conventional monitoring surveillance, equipment for monitoring signals from spacecraft must have adequate flexibility to cover a wide range of frequencies, in contrast to the spot frequency coverage that suffices for the needs of a research or operating space agency. The location of the monitoring station should be such that interference from man-made signals and noise is at a minimum.

Automatic sweeping of a band of frequencies, by varying the receiver tuning, and automatic recording of intercepted signals on a chart-type ink-line field-strength recorder, may assist in " acquiring " space signals and in timing their periods of reception.

An electronic counter, providing printed frequency and time records, has been found useful to meet the requirement of taking high-speed measurements to follow the Doppler shift.

For bandwidth measurements, it is desirable to employ a camera to photograph the spectrum display for later analysis. The exact time of taking the picture should be recorded on the film at the time of exposure.

Although good results have been obtained by tracking the satellite signals by manual adjustment of antenna azimuth and elevation, and by manual adjustment of the receiver tuning to follow the Doppler frequency shift, automatic tracking of both is suggested, if practicable. Further studies should be undertaken to determine practicable means to provide such tracking capabilities. Automatic antenna and receiver tracking will become of increasing importance for satisfactory monitoring at frequencies above 1000 MHz.

2.2 *Antennae*

Antennae ranging from fixed dipoles to log-periodic types capable of being rotated in azimuth and adjusted in elevation have been tested. The latter type has been employed for frequencies between 50 and 5000 MHz and has provided good general coverage over a 10 to 1 frequency range in a simple antenna. Other antennae used successfully include a multi-bay Yagi, single and twin helical, conical helix, dipole with corner reflector, folded crossed doublets with half-wave phasing stubs between the doublets, 4-element folded dipole (in-phase array), and a series of uni-directional " V " antennae with a selective switching arrangement to change orientation. Studies are progressing for the use of parabolic reflectors of up to about 8·5 m (28 ft) in diameter, for monitoring antennae to be used for frequencies in the 4000 MHz range and higher and using various antenna elements including a wide-band log-periodic array. Because of the quite sharp directivity of such high-gain antennae, considerable care is required in acquiring and tracking the signals from the spacecraft.

2.3 *Receivers*

For economic reasons, and because a general-coverage receiver is required at monitoring stations, the extremely low noise figures possible for fixed-frequency receivers used for space research and operational purposes are not equalled by available monitoring receivers. However, the receiver should have a relatively low noise figure and be capable of receiving signals in the order of a few hundredths of a microvolt at the receiver input, and should have a wide range of adjustable bandwidth to permit reception of both wide and narrow-band transmissions from spacecraft.

2.4 *Specialized equipment*

To facilitate " acquisition " of the signal from a spacecraft, it is desirable to be able to sweep a narrow band of frequencies automatically and to record the received signals both aurally and on a field-strength recorder. A sweeping device has been developed for this purpose, using a semi-conductor diode as a voltage variable capacitor applied to the frequency-determining circuits of the receiver. In operation, the sweeping device is set to vary the receiver frequency over a band greater than the amount of predicted Doppler shift.

3. Identification of transmissions from spacecraft

Considerable thought has been given to the extent of the need by space Administrations and by monitoring stations for a call-sign or other special identifying signal to facilitate identification of emissions from spacecraft and of the effects of installation of equipment for that purpose. It has been concluded that neither need is great enough at present, nor likely to be in the near future, to warrant pressing for the use of an identifying signal.

The techniques employed for space research and operations in satellite and other spacecraft tracking, and foreseen for communications and other uses of space emissions, are such that special identifying signals are normally not essential. There normally being no requirement on the part of the tracker and user for identifying signals, to require their use to facilitate monitoring observations, could impose limitations adversely affecting reliability, weight, cost and operation of the system involved.

It has been found possible to identify emissions from particular satellites from signal characteristics and ephemeris data. It would thus appear that the provisions of Article 19, No. 737 of the Radio Regulations, Geneva, 1959, relating to recognized means of identification other than call-signs, will be met if Administrations launching satellites and other spacecaft will continue to make such information currently available to monitoring services. The following information will assist in identification:

- carrier frequencies;
- orbit time;
- angle of inclination of orbit to equator;
- equator crossing time and longitude of crossing;
- perigee and apogee distances, and
- signal characteristics such as type of modulation and bandwidth for each frequency.

In addition, data on the transmitter power, antenna characteristics including antenna polarization and other related parameters will be useful in the prediction of reception.

From the ephemeris data, monitoring stations have been able to calculate when a particular satellite will be above the horizon for a particular monitoring station and the distances involved, to predict reception and assist in identification. A considerable amount of published information is available, regarding the techniques of satellite and spacecraft tracking and the problem associated therewith (see Bibliography).

3.1 *Special aids for determining satellite positions and expected reception times*

Graphical and slide-rule aids have been found useful for determining reception time for spacecraft based on past reception data (see Doc. VIII/3, Geneva, 1962).

3.2 *Direction finding as an identification aid*

To supplement determination of the exact time of closest approach of a satellite to a monitoring station, by noting the centre point of the maximum rate of the Doppler shift of the carrier frequency, a curve can be plotted to show the change in direction of arrival of the signal with time, as determined by direction-finder bearings or orientation of a highly directional receiving antenna. The maximum angular rate of change will occur when the satellite is nearest to the monitoring station during a particular pass and the information obtained by this method should agree closely with the information obtained from the frequency/time curve.

3.3 *Future possibilities for monitoring procedures involving transmissions from spacecraft*

Procedures have been discussed herein for identification of transmissions from spacecraft, based on past experience of comparing the measured and observed signal characteristics with published information, and by comparing the time of closest approach to a monitoring station – as determined from the measured Doppler shift of the carrier frequency and from varying azimuth (bearing) – with ephemeris data. With the expectation of increased use of operational satellites, immediate positive identification by monitoring stations of all intercepted spacecraft emissions by these methods may become too time-consuming. Therefore, the following additional procedures may be necessary:

- a communications system involving either passive or active satellites could be identified by the identifying signal of the ground station reflected from or relayed by the satellite, even if this did not immediately identify the particular satellite of a multi-satellite system, and
- in enforcement-type monitoring of spacecraft emissions, particularly when noncompliance with radio regulations or cases of interference are observed, monitoring stations could log all possible information concerning frequency and bandwidth measurements, direction of signal arrival, type of modulation and other signal characteristics, together with accurate times of observation and measurements, and request identification, based on these data, from identification and tracking centres.

The time that the satellite is closest to the monitoring location on a given pass, as determined from Doppler-shift measurements, and the carrier frequency as measured for this time, will be of utmost importance to the space centre in effecting identification.

However, further consideration might be given to the incorporation of an appropriate identifying signal.

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   - Weifenbach, G. C. Measurement of the Doppler-shift of radio transmissions from satellites.

REPORT 277-1 *

MEASUREMENTS AT MOBILE MONITORING STATIONS

(Question 144)

(1959 – 1963 – 1966)

1. Types of measurement

Subject to the limitations necessarily imposed by mobile operation, the size of suitable instruments and power consumption, it is considered to be practical to employ mobile stations to make all the measurements of emissions normally made at fixed monitoring stations.

Typical measurements and ranges are:

1.1 Frequency measurement:	10 kHz to above 10 GHz
1.2 Field-strength measurement:	10 kHz to above 10 GHz
1.3 Bandwidth measurement:	10 kHz to above 10 GHz
1.4 Direction finding – with loops:	10 kHz to 20 MHz
– with dipole arrays:	20 MHz to above 1 GHz
– with horns:	1 GHz to 10 GHz
1.5 Automatic monitoring of occupancy:	10 kHz to above 300 MHz
1.6 Percentage modulation, FM deviation:	10 kHz to 1 GHz
1.7 Video waveform measurement of television emissions:	40 MHz to 890 MHz

Mobile monitoring stations are particularly valuable for monitoring low-power stations and stations at frequencies above 30 MHz whose range is limited.

In addition to the use of equipment installed in a vehicle, certain measurements can also be made using portable equipment. Experience shows that separate mobile monitoring units, specifically designed for selected types of measurement, lend themselves more readily to operational use rather than a single vehicle equipped to make all classes of measurement.

2. Types of equipment

It is considered undesirable, to have to use special equipment for the mobile monitoring service and regular stock types of equipment with small dimensions, low weight and low power consumption are preferred. Since mobile equipment is subjected to vibration and shock, robust construction, together with shock-mounting of components, is important. With the exception of some portable units, the equipment is normally designed for operation at standard mains voltage and frequency.

It is preferred that instruments, such as frequency standards, which are sensitive to temperature changes, be designed to reach and maintain operating temperature in as short a time as possible, so that continuous application of power will not be necessary or so that only limited circuits will require continuous power. As an alternative, standards which are locked in synchronizm with VLF standard-frequency emissions should prove useful.

2.1 *Frequency standards and associated measuring equipment*

The frequency standard should be capable of maintaining a frequency stability one part in 10^8 per day or better, after nominal warm-up periods and under the operating

* This Report was adopted unanimously.

conditions normally encountered in the mobile service. Currently available frequency standards, specifically designed for mobile use, are capable of stabilities of $\pm$ 1 part in 10^8 or better under field conditions.

2.2 *Field-strength measuring equipment*

The extent to which field-strength measuring instruments should be provided in a mobile monitoring station depends upon the purposes of the measurements. For regulation enforcement purposes, continuous coverage up to at least 1000 MHz is desirable. For obtaining propagation data, highly sensitive recorders operating on a fixed frequency have certain advantages, although the instruments used for enforcement measurements may also be used for this purpose with some compromise in sensitivity and frequency stability.

This discussion will deal only with tunable continuous coverage instruments.

Wherever possible, field-strength measurements should be made in an area where the signal field is relatively undisturbed by local reflections and re-radiation. Where there is strong dependence on location, measurements may be made in terms of median values, the recording being made continuously as a function of location or time.

The mobile station itself may contribute errors and the calibration includes antenna, receiver and recording equipment. It is desirable, therefore, that the equipment be portable so that measurements can be made away from the vehicle. To avoid directivity effects when measurements are made from the vehicle in motion, omnidirectional antennae are used. Since measurements of harmonic attenuation may involve comparatively weak signals, it is desirable that the field-strength meter be capable of the measurement of signal levels of the order of 1 μV/m. The instrument should likewise be immune to overloading from strong signals of 1 V/m or more. To attain satisfactory accuracies, considering that undisturbed fields are the exception at frequencies above 30 MHz, the errors contributed by the instrument itself should be less than $\pm$ 2 dB. It is desirable that circuitry be incorporated for determination of peak and quasi-peak levels of pulsed emissions, as well as for the average field strength of amplitude- and frequency-modulated and similar emissions.

2.3 *Bandwidth measuring equipment*

Authorized bandwidths, for stations assigned to the various VHF and UHF services, vary from less than 1 kHz for radiotelegraph services to several MHz for television broadcast services. Mobile monitoring stations should, therefore, be equipped with spectrum analysers having very flexible characteristics, including a sweep width of 20 kHz or less for narrow-band emissions and with the capability of displaying at least 5 MHz of spectrum at a time on certain broadband emissions.

The sweep rate should be variable from about 1 to 30 sweeps per second to permit optimum utility for various types of observation. Provision should be made for either linear or logarithmic display of signal levels and calibrated scales should be provided for direct measurement of level ratios.

Mobile measurements of bandwidth may be made by a frequency occupancy recorder, for those types of modulation for which no measurement method of higher accuracy exists, or when it seems impracticable to carry out such measurements in the mobile service because of the high technical expense involved. With telegraph signals for instance, the bandwidth can be determined from the signal element with the shortest rise time (see Doc. VIII/10, Los Angeles, 1959). In the VHF band, estimated bandwidths can also be read off the oscillograph screen of a panoramic set with a calibrated frequency scale. The measurement of bandwidth can also be made by a method of frequency analysis, using a very narrow ($\pm$ 100 Hz) filter to measure the magnitude of the spectrum components passing through the filter in relation to the carrier.

2.4 *Direction-finding equipment*

It is desirable that the monitoring receivers in a mobile installation also serve as receivers for the mobile direction-finder. Light weight, compactness, high sensitivity, effective shielding, stability, robust construction and low power-consumption are desirable features for mobile monitoring receivers. Furthermore, receivers for mobile monitoring should provide continuous tuning coverage of as wide a frequency range as possible. Accurate calibration of the order of 1 kHz at 30 MHz and below, and 10 kHz above 30 MHz is highly desirable. Accuracy of frequency resetting of the order of 1 part in 10^4 or better is also desirable. Although band-switching is preferable, plug-in radio-frequency units for different bands may reduce the circuit complexity.

The loop rotater should preferably be installed in the approximate centre of the roof of the vehicle, with the loop socket extending through the roof and with the azimuth scale and rotating mechanism (usually a hand wheel) inside the vehicle at a convenient location. A number of plug-in-loops with different electrical characteristics will permit optimum results to be obtained over a wide range of frequencies.

Directional antennae are needed to extend the frequency range above the limits of loop antennae. Desirable characteristics are: high directivity, broadband frequency coverage, high gain, horizontal and vertical polarization and small size. Antennae types in use are horizontal and vertical dipoles, Yagi-beam, helical and rotatable H-type Adcock, while parabolic, horn type or corner-reflector antennae can be used above 300 MHz.

An antenna finding increasing acceptance above 1 GHz, is a broadband horn covering approximately a frequency range of 2 to 1. For added gain and directivity, the horn may be mounted in a parabolic reflector.

For antennae in the VHF/UHF range, it may be very useful to use telescopic rotating supports controlled from inside the vehicle employed as a mobile station. With these supports, it is possible to surmount obstacles near the place of measurement and to take measurements at various heights with the antenna steered in different directions. The antenna height and azimuth should be indicated accurately on the dials inside the vehicle.

2.5 *Automatic monitoring of occupancy measuring equipment*

Monitoring of spectrum occupancy, at specified locations or along specified paths, may be made in the mobile monitoring unit, by means of a frequency spectrum recorder or by means of a panoramic adaptor.

The latter permits visual observations to be made over a relatively small band of frequencies while the vehicle is in motion.

2.6 *Modulation measurement equipment*

It is desirable to provide facilities for measurement of percentage modulation of both amplitude- and frequency-modulated emissions. For the former, a cathode-ray oscilloscope with a wide-band vertical amplifier usable up to 10 MHz or more is required. For measuring modulation deviation of FM emissions, an instrument capable of accurate measurement of carrier deviation, over a range from $\pm$ 5 kHz or less to $\pm$ 100 kHz or more, is required and should be capable of indicating instantaneous values. An overall accuracy of 5% or better is highly desirable. A cathode-ray oscilloscope may be used as an indicator for the carrier deviation meter to permit measurements of instantaneous peaks of deviation of FM stations.

2.7 *Television measuring equipment*

Measurements of the characteristics of the video waveform of television transmissions can be made with instruments specially designed for the purpose. Cathode-ray oscilloscope display of the various portions of the video signal is desirable, so that individual picture lines or segments thereof, as well as individual synchronizing pulses, may be observed. Provision should also be made for viewing the entire picture on a screen of adequate size to permit evaluation of the picture quality.

2.8 *Power supplies*

To provide adequate power for large mobile monitoring units, a separate power unit either integral with the vehicle or mounted on a trailer may be used. An engine-alternator unit of 5 kW rating is usually adequate for this purpose. For the smaller mobile monitoring units, an alternator of about 500 W driven by the vehicle fan belt is a useful source of power.

3. Accuracies and limitations of measurement

Most of the measurements listed in § 1 of this Report can be as readily performed with mobile as with fixed facilities, generally with little or no compromise in desirable accuracy.

3.1 *Frequency measurements*

Mobile frequency standards are available which will maintain stability better than $\pm$ 1 part in 10^8 per day under field conditions.

By means of frequency synthesizers or electronic counters, it is often possible to obtain direct measurements of the frequency of emissions, without recourse to auxiliary interpolating instruments, over a range of frequencies extending above 100 MHz. Transfer oscillator techniques may be used at much higher frequencies, with interpolation between the transfer oscillator and the frequency standard being made with an electronic counter or other appropriate means. Measurement accuracies, within the desirable limit of $\pm$ 1 part in 10^7, may be accomplished under optimum conditions when the nature of the carrier is such, that a precise zero beat may be obtained or where direct counting techniques may be used.

On FM emissions, frequency averaging techniques with an electronic counter will provide an accuracy of 1 part in 10^6 or better.

3.2 *Field-strength measurements*

The accuracy of field-strength measurements above 30 MHz is limited, not so much by the instruments themselves, as by the local conditions and transmission-path which tend to distort the electromagnetic field, so that a considerable variation in field-strength over relatively short distances may be expected. This problem may be alleviated to some extent by making several measurements at each measuring location, moving the antenna a few feet horizontally between measurements. Very good results can also be obtained by taking measurements at different heights using the telescopic supports described in § 2.4 [1].

Under average conditions, even when appropriate precautions are taken to ensure optimum accuracy, the accuracy cannot be depended upon to be better than $\pm$ 2 dB. If large numbers of measurements are made as functions of time, location or distance, etc., the statistical evaluation will yield values of the quasi-maximum, quasi-minimum and median values with an accuracy of about $\pm$ 3 dB or better, depending somewhat on the distribution of field-strengths. A major limitation of portable or mobile field-strength meters is the limited sensivity, particularly at the higher frequencies. In the lower portion of the spectrum, up to several MHz, atmospheric noise is likely to be a limiting factor on the usable sensitivity, while at higher frequencies the noise introduced by the instrument itself becomes important. Under average field conditions and depending upon the frequency involved, the minimum field-strength, which may be measured with portable instruments with the accuracies mentioned above, will range from about 2 to 100 µV/m in the frequency range from 10 kHz to 1000 MHz.

3.3 *Bandwidth measurements*

Generally, the same limitations apply on measurements of bandwidth by mobile installations as for measurements at fixed monitoring stations. The same measuring instruments are applicable to both types of installation. One advantage of mobile as contrasted with fixed installations is that, in the case of the former, measurements can often be made immediately adjacent to the transmitter, eliminating some of the measurement problems (such as those associated with interference and noise), which are mentioned in Report 275-1.

3.4 *Direction finding*

A major limitation of loop-type direction-finders is their polarization error in the presence of signals with significant skywave components. A further serious limitation of a direction-finder, which depends upon the direction of arrival of the wave front, is the likelihood of local reflections or re-radiation from nearby objects such as buildings, transmission and telephone lines, etc. In an area where the wave is relatively free from distortion due to local conditions, where the path of arrival is essentially horizontal (vertically polarized wave), and taking into account possible errors introduced in orienting the direction-finder azimuth scale, accuracies of the order of $\pm$ 5° with vehicle-mounted loop-type direction-finders are typical, with somewhat greater accuracy at frequencies below about 5 MHz. However where the wave has been distorted by local conditions or where skywave components are present, bearing nulls are likely to be obscured or to deviate widely from the true direction of the emission source.

Where the ground wave is predominant (i.e. the ratio of ground-wave to reflected waves being at least 6 dB), direction-finding loops may be used in the frequency range 10 kHz to 30 MHz. The accuracy obtained depends upon the signal level and the equipment used.

Typical values for a direction-finding null 1° wide are:

10 kHz: 50 µV/m,
1000 kHz: 15 µV/m,
20 MHz: 10 µV/m.

For the bearings of horizontally polarized signals (line-of-sight) at frequencies above 30 MHz, Yagi-beam antennae may be used in a method of maximum signal direction-finding with an angular width of bearing indication of $\pm$ 15°.

For measurements made from a vehicle in motion, no proper bearing seems possible because of multiple reflections from nearby objects. However, when equipped with a visual indicator, mobile direction-finding sets will allow determination of a median value of the varying indications and hence yield an approximate direction.

3.5 *Monitoring of occupancy of the radio-frequency spectrum*

The accuracy obtainable from a frequency spectrum occupancy recorder depends upon the receiver and the overall calibration. Equipment used in the Federal Republic of Germany has the following characteristics:

- Sensitivity: better than 1 µV/m.
- Accuracy of field-strength indications: $\pm$ 3 dB at angles of incidence below 60°.
- Frequency stability of receiver: $\pm$ 5 parts in 10^5 $\pm$ 40 Hz (where $\pm$ 40 Hz is the bandwidth of the filter).
- Accuracy of reading time-markers: $\pm$ 1 min or $\pm$ 30 s.
- Adjustable maximum frequency spread on the recording strip by choice of appropriate gear reduction: 100 Hz per mm. When monitoring above 30 MHz by means of panoramic sets the resolving power may be about 400 Hz.

3.6 *Percentage modulation*

Cathode-ray oscilloscopes, with the desirable characteristics for measurement of percentage modulation of amplitude-modulated signals, are available. Accuracy of such measurements can usually be maintained within ± 5%. For measurement of carrier deviation, instruments are available which meet the desirable characteristics listed in § 2.6. Self-contained calibrators are provided to maintain an instrument accuracy better than 5%.

3.7 *Television measurements*

Instruments are available for performance of all desirable television measurements and observations mentionned in § 2.7. Measurement accuracy of the various instruments in most cases approaches or equals that of measurements which can be performed at a fixed location. Comparative level measurements of components of the composite video waveform, for example, can usually be made with an accuracy of 5 to 10%.

Measurements and observations, which may be performed with the equipment installed in a mobile television enforcement unit in the U.S.A., include:

- frequency measurements of television station carriers (including chrominance sub-carrier frequency of colour emissions);
- the precision frequency measuring equipment covers a frequency range of 20 to 1000 MHz with an accuracy under optimum conditions of 5 parts in 10^7;
- measurements of synchronizing pulse waveform and timing, video waveform and of colour video phase relationships;
- checking of video levels with respect to synchronizing pulse levels;
- measurements of bandwidth of television emissions including observations of spurious emissions at all frequencies between 54 MHz and 890 MHz;
- percentage of modulation rate of vision and sound emissions;
- measurements of distorion and noise level at audio frequencies.

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REPORT 278-1 *

AUTOMATIC MONITORING OF OCCUPANCY OF THE RADIO-FREQUENCY SPECTRUM

(Question 9/VIII)

(1959 – 1963 – 1966)

This Report takes into consideration the documents presented up to the XIth Plenary Assembly of the C.C.I.R., Oslo, 1966.

1. Doc VIII/2 (U.S.A.), Washington, 1962

1.1 In considering the accuracy of automatic monitoring equipment in determining bandwidths of emissions, due consideration should be given to relating measurements of narrow-band emissions of the order of 2 kHz or less to the characteristics of the particular instrument

* This Report was adopted unanimously.

in use. It has been determined, for example, that in some instruments which mechanically sweep a frequency range and resolve the bandwidth presentation by selective circuits, the shape factor of the selective circuits is such as to complicate bandwidth determinations at other than accurately known comparison levels. The variation of received signal levels due to propagation conditions, together with other factors, impose restrictions on the accuracy of indicated signal bandwidth of narrow-band signals. Consideration should therefore be given to the need for an analysis of the relative distribution of the signals level and the resolving capability of the instrument at several input levels. For signals with bandwidths of several kHz, the errors contributed by the above-mentioned equipment limitations become less important. Nevertheless, it may be desirable, in the interest of correlating data obtained with different instruments, to take into account their resolving power and the repetition rate and duration of discrete components of the observed signals.

In determining the accuracy of field-strength measurements made by automatic devices, the polarization and directivity of the antennae are important factors. In the 3 to 30 MHz range, where signals received over sky-wave paths contain both horizontally and vertically polarized components to a significant extent, a decision must be made as to the component to be measured. Since the vertical angle of arrival is most commonly less than 45°, less error will usually be introduced by measuring the vertically-polarized component rather than the horizontally-polarized component. Where greater accuracy is required, an appropriate correction may be applied, based upon a computed value for the vertical angle of arrival of the wave front.

Measurement of the vertically-polarized component may readily be accomplished by using a vertical receiving antenna, the electrical length of which is appreciably less than one-quarter wave, for the frequency band under study. To reduce errors due to non-homogeneous earth in the vicinity of the antenna, a ground screen, together with radial ground wires extending out at least 30 m (100 ft.) in all directions has been found beneficial. The level of signal input to the recorder may be measured by comparison with a calibrated standard radio-frequency signal generator. The antenna effective height is determined by comparison with measurements made with an accurate field-strength meter using an antenna of like polarization.

In evaluating the field-strength data thus obtained, due allowance must be made for errors introduced by the various instruments. Allowance must also be made for fluctuations in signal-level, since, during the sweeping process, the receiver is tuned to a particular signal for only a small proportion of the time.

1.2 Measurement of signal-to-noise ratio primarily involves a comparison between signal and no-signal conditions making use of the same techniques as for field-strength measurements. In this instance too, variations in signal-level due to propagation must be taken into account. In the lower portion of the HF range, the problem is somewhat complicated, especially during the warm months of the year, by the generally high level of atmospheric noise, which is subject to wide variations in level, both instantaneous and over significant periods of time. The effect of receiver bandwidth and of the bandpass characteristics will also need to be considered, so that satisfactory correlation between measurements made with different equipment may be accomplished.

1.3 The preferred means of analyzing and evaluating automatic monitoring records depends primarily upon the information desired. In some instances, it may be desirable to obtain information concerning the direction of arrival of the various signals in the frequency band under study; this would provide data relating to the determination of channel occupancy with respect to the different azimuths of origin of the emissions. For example, a long-range direction-finder may be associated with the automatic recorder in such a way that the azimuth would be advanced a small increment (such as one or two degrees) at the start of each sweep of the automatic recorder. Signal nulls and maxima could readily be determined by inspection of the chart. Additionally, data could be extracted from such recordings which would indicate occupancy in a given azimuth at regular intervals of time. In congested bands, the use of a directional antenna would also aid in reducing overlapping of signal traces.

Identification of the type of emission, by analysis of automatic recorder indications, is subject to shortcomings with narrow-bandwidth emissions, because of limitations in the resolving power of the instrument. However, those emissions occupying a significant bandwidth, such as multi-element tone printers, multiple-component multiplex, wide-shift simplex or multiplex and certain transient types of emission, can frequently be catalogued by inspection of recorder indications, together with precise frequency increment chart calibration.

1.4 The degree to which records may be analyzed by automatic means would appear to be an economic rather than a technological matter. Because of the variety of data normally available from the automatic recorder, equipment for complete automatic analysis would necessarily be quite complicated. Such an analysing system might employ transducers to convert chart components into digital or analogue data which could be handled by electronic data-processing equipment.

2. Doc. VIII/8 (Federal Republic of Germany), Washington, 1962

The method of measurement described below permits the field-strength to be recorded continuously instead of in steps. From such field-strength recordings, the bandwidth and signal-to-noise ratios may be readily determined.

A potentiometer is mechanically coupled to the recording head of the occupancy recorder, supplying a d.c. voltage directly proportional to the relative position of the recording stylus on the recording sheet. After suitable amplification, this d.c. voltage is applied to the time base (x-plates) of a cathode-ray oscilloscope, thus providing a frequency scale exactly in synchronization with the sweep of the occupancy recorder.

The intermediate-frequency output of the receiver is connected to a multi-section analyzing filter (quartz crystal), the bandwidth of which is variable in steps between 30 and 100 Hz. After detection, the filtered signal is amplified in a logarithmic amplifier and fed simultaneously to the measuring (Y) plates of the oscilloscope and to the occupancy recorder. By special arrangements, the Y-axis is calibrated linearly over a range of 80 dB. The oscilloscope screen, of the long-persistence type, allows direct observation during a full sweep of the occupancy-recorder. Automatic recording is effected by photographing the screen presentation of any individual sweep by means of a 35-mm camera. The shutter release may be actuated automatically, by means of a special control contact in the occupancy recorder. By means of a simple counter device, such as is used in telephone exchanges, it may easily be arranged that each single or any *n*th sweep is exposed on the film. Correlation between the photographed oscillograms and their corresponding sweep numbers is easily ascertained by photographing the counter, together with the spectrum pattern.

Evaluation of the oscillograms may readily be performed by projecting the developed negative on to the occupancy recording sheet, so that both frequency calibrating scales are made to coincide. The field-strength and bandwidth of a wanted emission, as well as its amplitude ratio relative to an unwanted signal, may thus be determined easily. The values taken from the photographs are, of course, instantaneous values present at a particular point of the spectrum at the moment when the filter swept through it.

The foregoing characteristics point to the limitations of the proposed method. Setting aside for the moment the influence of fading, which will be dealt with further below, the proposed method is suitable for recording continuous line spectra as well as periodically and quasi-periodically keyed emissions, i.e. practically any binary telegraph systems encountered in practice. Some difficulties arise, however, in the representation of non-periodic pulse emissions and of classes of emission with modulation envelopes which do not vary periodically; e.g. A3, A3A, A3B; in these cases, however, the amplitude of the carrier (or residual carrier) is recorded correctly.

The extent of the frequency range that can be explored is limited by the bandwidth of the analyzing filter which, to assure the desired resolution characteristic, should not be larger than 100 Hz, and by the exploration speed which should not greatly exceed 60 s per sweep. Since, for the intended purpose, the exploration rate with a filter width of 100 Hz should be 5000 kHz per second the time increment for any discrete spectrum component of the sweep signal is in this case 20 ms; the scanning speed of spectrum analysers given in Annex I to Recommendation 327-1 are considerably lower, because fine analysis of the spectrum is desired. In most cases, however, the indication of field-strength, as found from the oscillograms, will be entirely adequate to give an overall picture of the conditions in the frequency range explored. This holds true similarly for the bandwidth and signal-to-noise ratios of the recorded emissions. In these conditions, the maximum sweep range would be 300 kHz wide. Recordings of signals subjected to fading can, of course, only show instantaneous values of the field-strength. The received field undergoes irrégular variations between limits that can only be estimated by taking a large number of sequential photographs. Any estimate of the actual field-strength will normally be accurate within ± 4 dB. The smaller the scanning range, the better the field-strength maximum will be discernible. If, in special cases, a more accurate measurement of the statistical variation of the field-strength is desired, a conventional single-frequency recording with subsequent analysis should be made.

3. Doc. VIII/12 (Japan), Washington, 1962

3.1 The recording system is of the disruptive-discharge type, so that the records can be examined in the course of recording. Moreover, the recorded lines are very thin and the field-strength of signals can be indicated by the thickness of the lines.

3.2 Since the filter in the recording unit (the rate of sweep being taken into account), has a passband 30 Hz wide, it resolves the frequencies very well. This enables one to identify the type of emission from the recording.

3.3 The frequency stability of the receiver unit is better than 1 part in 10^6 and the frequency scale (capable of calibration against the standard frequency), can be marked at 10 kHz intervals. Therefore, the accuracy of reading the frequency is 300 Hz;

3.4 To determine the relative field-strength of each of the vertically recorded lines, a variable attenuator is placed at the intermediate-frequency stage in the receiver unit, and is inserted automatically step-by-step in succession at each fixed time of sweeping. Thus, the relative field-strength can be obtained from the amount of attenuation inserted.

Furthermore, to smooth the overall gain/frequency characteristics of the equipment, including the antenna system used, a vertical omnidirectional loaded antenna of wide bandwidth is used (the structure and electrical characteristics of which are shown in Figs. 1, 2 and 3 in Report 373).

3.5 *Accuracy in determining bandwidth*

This equipment is to record the relative distribution of the spectra of signals above a certain level, but it is not intended that the occupied bandwidth, as laid down in the Radio Regulations, Geneva, 1959, should be read from the recorded lines. Therefore, as the width of the spectrum of each signal at a certain level is considered as a bandwidth, studies were carried out to determine the accuracy with which the bandwidth might be estimated in this case.

This equipment, when used with a 100 kHz swept frequency range and 60 sweeps per hour, is capable of determining the bandwidth of the spectra of various classes of emission at a given level to an accuracy of about 100 Hz.

3.6 *Accuracy in determining field-strength*

The method of measurement of field-strength by means of this equipment is the same as described in § 3.4. In this case, the larger the number of sweeps per step in the attenuator, the higher the accuracy of reading the recorded lines. Considered from the propagation characteristics, however, because of variations in field-strength, the increase in the number of sweeps and the prolongation of measurement brings a lack of reliability to the results.

On the other hand, in the field of reception at the monitoring stations in Japan, almost all radio waves, excluding those in the standard broadcasting service, are less than about 55 dB (1 μV/m = 0 dB). The lowest field-strength that this equipment is capable of recording is − 10 dB.

From various viewpoints above, it is concluded that it is best to complete one operation of measurement in a period not exceeding 20 minutes at 60 sweeps per hour, the number of sweeps per step of the attenuator being 2, and the attenuator having 10 steps of 6 dB each, that is, 60 dB.

Where measurements are taken with the 100 kHz swept frequency range by the use of the equipment with the above characteristics:

- the overall gain deviation of the vertical omnidirectional loaded antenna and the receiver unit within the swept frequency range is within ± 0·8 dB;
- the accuracy of reading the field-strength from the result of recording is within ± 4 dB;
- the error of the attenuator at the intermediate-frequency stage is within ± 1 dB.

Taken altogether, the accuracy of determination of the relative field-strength is ± 6 dB. Further, if a suitable emission is selected from among those recorded and its field-strength is measured individually, the relative field-strength of each emission can then be obtained.

3.7 *Capability of automatic monitoring equipment in determining signal-to-noise ratios*

The lowest signal-to-noise ratio (for an equivalent noise bandwidth of 10 kHz) that this equipment is capable of recording, is less than − 10 dB at the input terminal of the receiver, when the equipment is in the optimum condition of recording. In case of higher values than this, the signal-to-noise ratio can be determined by measurement of the intensities of signal and noise in the same way as the field strength mentioned above.

4. Doc. VIII/11 (Japan), Washington, 1962

4.1 *Measurement of relative field-strength*

A variable attenuator is added to the receiver unit of the equipment, the attenuation is automatically increased step-by-step in succession at each specified number of times of sweeping, and the signal output is recorded. The relative field-strength of each signal is determined by the attenuation inserted immediately before the recorded line fades out.

The absolute field-strength is obtained as follows: the absolute value of the wanted signal among those recorded is measured by means of a second field-strength meter, and, on the basis of this value, the absolute value of other signals is derived from the relative field-strength.

The total attenuation should be 60 dB, to be equally divided into about ten steps. It is desirable to make the number of times of sweeping two per step in the attenuator.

The duration of each measurement should be about 20 minutes, taking account of fluctuation in field-strength due to variation in the radio propagation characteristics.

An antenna, with good frequency characteristics such as a vertical omnidirectional loaded antenna, should be used (such an antenna is illustrated in Fig. 1, and its characteristics are given in Figs. 2 and 3 in Report 373).

5. Occupancy-vacancy recorder

An occupancy-vacancy recorder in use in the U.S.A. and initially described in Doc. 186 (U.S.A.), Los Angeles, 1959, has been modified especially for use on 30 to 470 MHz, although it may also be used for 500 kHz to 30 MHz coverage if desired. The basic unit consists of a receiver mechanically tuneable from 500 kHz to 30·5 MHz in steps of 1 MHz. Operation at VHF and UHF is obtained by the use of converters changing the frequency being recorded to frequencies between 15·5 and 30·5 MHz. The converters are normally operated with crystal frequency control although occasionally synthesizers have been utilized.

A common drive mechanism drives both the receiver tuning mechanism and the recording chart. After the 1 MHz band is scanned the receiver and chart are returned to the starting frequency at high speed. The frequency axis is along the 122 cm (48 inch) length of the chart and the pen moves across the 30·5 cm (12 inch) width of the chart in 48 hours. When a signal is received above a level determined by the sensitivity setting of the receiver, the recording pen drops against the paper and marks. (During the high-speed return span the pen is lifted from the paper.) The resulting record is a sheet 30·5 × 122 cm (12″ × 48″) with the occupancy information for a given frequency appearing transversely on the chart. If desired there is provision for changing the receiver sensitivity on the 2nd and 3rd scans and returning it to the original value on the 4th scan.

The present mode of operation is as follows:

Bandwidth covered per sweep:	1 MHz
Time of sweep and return (total):	5·5 min
6 dB bandwidth of recorder:	6 kHz

Presentation: paper and ink, 30·5 × 122 cm (1 × 4 feet)

Sensitivity: approximately 1 μV across 50 Ω

Antennae: Vertical stacked omnidirectional antenna for 148-172 MHz and 450-470 MHz
Vertical omnidirectional ground-plane antenna or half-wave dipole for 30–50 MHz.
The antennae used have a gain of about 2 dB over a half-wave dipole at 150 MHz, 6 dB at 450 MHz and a slight loss at 30 MHz.

The VHF and UHF converters are designed to minimize spurious responses and additionally are preceded by high and low-pass filters to guard against strong local signals outside the swept band.

6. Doc. VIII/86 (F.S.R. of Yugoslavia), 1963-1966

This refers to an apparatus for the automatic monitoring of operation and occupancy in time of a given frequency. The apparatus is used to monitor occupancy of specific frequencies (ascertaining the number of stations working on the same frequency and the occupancy rate), for making automatic tape-recordings of the monitored transmissions for the duration of the working signal, subsequently to identify transmissions, if necessary, to warn the monitoring cabin of an expected transmission, to make time-signal recordings on the same tape of the end of the transmission, using the talking clock of the telephone exchange.

The apparatus is started and stopped by a working signal produced by the monitored frequency.

Any receiver and a standard tape recorder, or other transmission recording instruments, can be connected to the apparatus. It can operate either as a permanent monitor or for the period of the watch, scheduled in advance, on the frequency concerned.

The working signal of the receiver from the intermediate-frequency terminal, the audio-frequency terminal or the d.c. terminal of the automatic gain control is used as triggering signal. After amplification, amplitude limitation and signal detection, a polarized relay is used and its sensitivity can be regulated.

To prevent unwanted triggering of the apparatus by atmospherics, variable time-constant elements are incorporated in the detector stage to obtain a delay effect.

The criterion adopted to avoid mis-triggering is the duration of the control signal.

At the end of the transmission, the polarized relay clears after a slight delay, which is necessary to avoid an unwanted break in the recording due to the pause between the letters or words in the case of an A1 emission.

A stage, with a time constant of 20—30 s, after the end of the transmission ensures continued operation of the apparatus while the telephone number of the talking clock is being dialled to record its time signals on the same tape. The telephone line is occupied only while the time is being recorded.

An automatic process comprising a " mechanical finger " and the standard telephone dial is used for dialling this number.

In case this number is busy, a special selective stage is provided which uses the characteristics of the busy signal and sets the whole switching process in motion again.

Recording of the working time with this apparatus is very accurate, with a tolerance of ± 10 s.

7. Doc. VIII/19 (Japan), 1963-1966: Mobile equipment for the automatic monitoring of occupancy of the radio-frequency spectrum and its performance

7.1 *Principal characteristics of the equipment*

7.1.1 The recording system is of disruptive-discharge type, so that records can be examined in the course of recording. Moreover, the recorded lines are very thin and the strength of signals can be indicated by the thickness of the lines.

7.1.2 The sweep rate (120 per hour) being taken into account, the filter in the recording unit has a passband less than 1 kHz wide, and so it resolves the frequencies very well. This enables one to identify the class of certain emissions from the recorded diagrams.

7.1.3 The frequency stability of the receiver unit is better than 1 part in 10^4 and the frequency scale can be marked at 200 kHz intervals. This scale can be calibrated by means of a built-in frequency standard.

7.1.4 The frequency range is approximately between 40 MHz and 200 MHz (the upper limit may be extended to 500 MHz).

7.1.5 The swept range is 3 MHz.

7.2 *Facilities for analysis of the records*

7.2.1 *Accuracy of reading the frequency*

At the beginning of the recording, the frequency scale can be marked by a calibrating crystal oscillator. The frequency can be read, by interpolation, from the recorded lines of received signals against the calibrated frequency scale. The accuracy of reading is determined by the difference between the frequency measured in the field and that read from the records (the centre of the band for frequency-modulation signals and the recorded line corresponding to the carrier for amplitude-modulation signals), and is given as follows:

for amplitude-modulation signals: ± 5 kHz;

for frequency-modulation signals: ± 7·5 kHz.

The accuracy for frequency-modulation signals with constant bandwidth is approximately the same as for amplitude-modulation signals.

7.2.2 *Identification of the class of emission*

The class of certain emissions can be easily identified from the shape and frequency spacings of the recorded lines.

7.2.3 *Accuracy of determining the bandwidth*

This equipment is to record the relative distribution of the spectra of signals above a certain level, but it is not intended that the occupied bandwidth, as laid down in the Radio Regulations, Geneva, 1959, should be read from the recorded lines; therefore, the width of the spectrum of each signal at a certain level is considered as the bandwidth for our purpose and studies were carried out to determine the accuracy with which the bandwidth might be estimated. The width of the recorded lines of the signals of various classes of emission is read against the calibrated frequency scale and the precision of reading is about 3 kHz.

7.2.4 *Frequency resolving power*

The result of the test gives a resolving power as fine as 6 kHz.

7.2.5 *The lowest field-strength*

This equipment consists of a receiver unit with a variable attenuator; therefore the lowest field strength that this equipment is capable of recording is determined by the field strength measured when the recorded line disappears, as the signal is gradually reduced by means of the variable attenuator.

The test was conducted in the 150 MHz band and an antenna gain of zero dB was used and gave the following results:

for amplitude-modulation signals: $-$ 5 dB rel. 1 μV/m;
for frequency-modulation signals: $+$ 5 dB rel. 1 μV/m.

REPORT 279 *

VISUAL MONITORING OF THE RADIO-FREQUENCY SPECTRUM

(Question 10/VIII)

(1963)

Question 10/VIII seeks information on preferred equipment and preferred methods for visual monitoring of broad ranges of the radio-frequency spectrum. The following is a report of progress to date, as summarized from the responses to this Question (Docs. VIII/9 (U.S.A.), VIII/19 (Belgium), and VIII/26 (United Kingdom), Washington, 1962).

Except for the use of spectrum analysers for signal analysis, and use of panoramic-type receivers or adapters for observation of limited widths of the radio spectrum, stations of the international monitoring system have reported little actual experience in visual monitoring operations. Further development of methods and procedures must await actual experience in the use of broadband spectroscopes at monitoring stations.

1. Spectrum analysers are valuable in the recognition and classification of emissions, especially complex emissions. The spectrum analyser is a scanning type of instrument arranged to display, on a cathode-ray tube, the spectral contents of the frequency band under examination. Spectrum analysers of various types are under development or in operational use.

* This Report was adopted unanimously.

1.1 A spectrum analyser, described in Doc. VIII/26, can be used as a panoramic receiver covering the frequency range of 25 MHz to 140 MHz and employing a wide sweep. The width of the sweep can be varied continuously between 1% and 55% of the tuned frequency. Two output filters are incorporated, one with 7 kHz bandwidth for sweeps up to 5 MHz, the other with 35 kHz bandwidth for sweeps of over 5 MHz. Resolution varies from 8 kHz for a 250 kHz sweep to 100 kHz for a 70 MHz sweep. Sensitivity varies between + 48 dB and + 54 dB relative to 1 μV across 75 ohms, for frequencies of 25 MHz and 40 MHz respectively, to give full deflection on the screen. Frequency markers at 10 MHz intervals and at 2 MHz intervals can be applied at will, appearing as a bright (or dark) spot on the trace, the 10 MHz markers being distinguished by double spots.

1.2 The principle of design of a spectroscope is described in Doc. VIII/9. The first of these units is expected to cover frequency range 100 MHz to 1000 MHz. The ultimate range of the equipment is expected to be 14 kHz to 10 GHz. The principle involved is that of heterodyning the incoming signals by means of a local sweeping oscillator to produce an intermediate-frequency. Increased selectivity is obtained by further conversion to a second lower intermediate-frequency. Selective filter bandwidths of 5 MHz, 1 MHz and 400 kHz are obtained at 775 MHz. The first intermediate-frequency of 775 MHz is converted down to 30 MHz where, using crystal filters, bandwidths of 25 kHz and 5 kHz are obtainable, enabling relatively fine spectral details to be observed. This allows selection of the desired bandwidth and resolution commensurate with the sweep rate selected which should be continuously variable over a wide range. Read-out may be either linear or logarithmic. In the latter instance, a separate amplifier is provided to give a dynamic range of 140 dB for display of relative signal strengths. A large 43 cm (17 inch) cathode-ray tube is used for displaying the spectrum, the vertical displacement being a function of the signal strength and the horizontal sweep being synchronized with the sweep of the local radio-frequency heterodyning oscillator. The average overall sensitivity of the equipment at 5 MHz bandwidth should be approximately — 90 dBmW. Tests have indicated that 100 to 1000 MHz wide band radio-frequency amplifiers for use with a radio-frequency spectroscope are capable of a 6–9 dB noise figure, a gain of 25–40 dB, a sensitivity of — 105 dBmW and an image rejection of better than 60 dB.

1.3 A wide-band spectrum analyser is available commercially which can be used by monitoring stations for visual observation of a band 70 MHz wide in the range 10 MHz to 44 GHz. With two dispersion ranges, 0 to 70 MHz and 0 to 5 MHz, it can be used for broadband observations of up to 70 MHz. The analyser is normally equipped with a 13 cm (5 inch) display oscilloscope; however, a 43 cm (17 inch) oscilloscope is available for comprehensive frequency monitoring.

2. It has been found that a panoramic view of a broad portion of the radio-frequency spectrum can be presented on a cathode-ray tube, by the use of suitable sweep circuits in the radio receiver or in an associated panoramic adapter. Panoramic receivers or panoramic adapters are under development or in operational use.

2.1 A panoramic receiver is described in Doc. VIII/26, which consists of an HF communications receiver and a panoramic adapter in a single cabinet, to provide a visual oscilloscope display in any selected band between 1 and 30 MHz. Scanning is limited to a band lying between two adjacent multiples of 1 MHz. Sweep width can be varied continuously between 60 kHz and 1·04 MHz. The frequency of the sweep can be either 1 or 10 per second. Output filters 1·2 kHz, 3 kHz, and 8 kHz are provided. Either linear or logarithmic presentations are available. 100 kHz frequency markers can be applied at will.

2.2 Panoramic equipment, designed for visual supervision of mobile services operating in the VHF bands, is described in Doc. VIII/19. A panoramic adapter used with a VHF receiver covers the bands 30 to 180 MHz or 85 to 300 MHz with an intermediate-frequency of 21·4 MHz. Spectrum width is 1·2 MHz. The selective filters consist of three fairly low frequency (2 MHz) amplification stages, in the form of three double-tuned transformers adjusted below the critical coupling. Visual display is made on a 13 cm (5 inch) oscilloscope.

2.3 A second type is not associated with an external receiver and does not include sound. The radio-frequency spectrum from 70 to 190 MHz is examined in small sub-bands of 10 MHz, harmonics from a 1 MHz crystal oscillator are introduced into the pre-amplifiers; reference markers at 1 MHz intervals are thereby obtained on the oscilloscope. Visual display is made on a 13 cm (5 inch) oscilloscope (Doc. VIII/19).

3. Cathode-ray tubes of various size are employed for visual observation. A 43 cm (17 inch) tube with a P-7 screen and amber filter is suggested on the basis of studies to date. Further development may make practical the use of larger tubes, or multiple-trace tubes, to extend the frequency axis of the display (Doc. VIII/9).

4. To provide a uniform response in amplitude read out on the broadband spectroscope display, it is of course necessary to employ wideband antennae. In using the spectroscope for simultaneous observation of a large part of the spectrum, it is necessary to compromise on the selection of the antennae. The antennae giving the best results with spectroscopes are: rhombics, log-periodic types, and vertical antennae which are shorter than a quarter wavelength at the highest frequency under observation (Doc. VIII/9).

5. Recent developments in the design of broadband amplifiers, and their availability, leave few, if any difficulties regarding the broadband radio-frequency amplifier units for spectroscopes. One wideband amplifier has a frequency response flat within ± 1·5 dB from 1 kHz to 200 MHz, a voltage gain of 20 dB, a noise figure of 9 dB and a rise time of less than 0·0026 μs (Doc. VIII/9).

6. Conclusions

Within the next few years, it is expected that various types of " broadband " spectroscopes for visual monitoring will become available for use at monitoring stations. The trend in design and construction of spectrum analysers is towards an increasing value of total scanning excursion (sweep width).

Several units will probably be required to cover the spectrum simultaneously from 10 kHz to 1000 MHz; however, at the present time no need has been shown for such simultaneous coverage. Rather, a monitoring station will probably find it more convenient to observe only one broad segment of the spectrum at a time.

Actual experience is needed in developing operating methods and techniques in the use of " broadband " spectroscopes for monitoring purposes. Therefore, it is advisable that studies under Question 10/VIII be continued.

REPORT 280-1 *

IDENTIFICATION OF RADIO STATIONS

(Question 14/VIII)

(1956 – 1959 – 1963 – 1966)

1. This Report summarizes the contributions and discussions in response to Question 14/VIII. It also retains that material from Report 280-1 which was considered to have an application to the adoption by Administrations and operating agencies either of the provisions of Recommendation 379-1 or of other methods of identification and operating procedures relating thereto, as discussed in this Report.

2. Since the IXth Plenary Assembly, some progress has been made, particularly with respect to phase-modulation of multichannel FSK systems, whereby the identifying signal can be sent simultaneously into all circuits using the same sub-carrier. This results in centralization of identifying signals (Doc. VIII/14 (Japan), Washington, 1962).

2.1 The sub-carrier is directly phase-modulated by the modulator circuit added to the transmitting terminal equipment, and the identifying signal can be supplied simultaneously to all circuits using the same sub-carrier, by means of a distribution amplifier.

Because of the small modulation index required, a simple device consisting of a single transistor is sufficient for the purpose. The modulated signal is keyed in Morse code and its amplitude adjusted so that, whatever the class of amplification, the specified modulation index is independent of the frequency of the emission, type of emission, etc. The modulation index can be measured accurately during the operation time of the circuit regardless of traffic in progress.

The intelligibility of the identifying signal is affected by the modulation index and the modulating frequency. In F1 or F6 emission, the modulation index is suitable at 0·05 and no great difference in intelligibility occurs for modulating frequencies between 500 to 1000 Hz. In a composite circuit of F1 and F6 emissions, it is desirable to have the modulation index greater than 0·05 and the modulating frequency no less than 600 Hz.

3. Two additional methods have been used for identifying F1 emissions simultaneously with traffic:

3.1 One method (Doc. 468, Warsaw, 1956), is to superimpose an audio-frequency modulation which produces a phase-modulation at the transmitter output. A low-level amplitude-modulation is applied to the exciter and this ultimately produces phase-modulation through the limiting action of the following class C amplifier. The audio tone is keyed and applied across the common cathode resistor of the balanced modulator. This results in the production of additional sidebands on either side of the main carrier with a displacement depending on the frequency of the audio tone employed.

It has been found that satisfactory identification is obtained without interference to traffic, if the amplitude of the sidebands is about 32 dB below that of the carrier. Continuous repetition of the identifying signal at a rate of 8 w.p.m. is used. The keying device consists of a notched " keying wheel " through which a beam of light is projected thereby operating a photo-electric cell. An ordinary communications receiver, with the beat-frequency oscillator turned off, is used for reception of the keyed identifying signal.

3.2 Another method has been developed which superimposes on the carrier an additional frequency-modulation at small index and at 400 Hz, keyed by the identifying signal. The conditions under which the method is used and the results obtained are described in Doc. 183, Los Angeles, 1959.

* This Report was adopted unanimously.

4. Keyed amplitude-modulation, which is superimposed on frequency-modulation for identifying signals has, for economic reasons, not been generally applied because the method used employed high-level modulation.

A method for identifying single-sideband multi-channel systems by the insertion of a keyed audio tone on one of the channels was found to be unsatisfactory due, particularly, to the difficulties encountered by monitoring observers.

5. Since the Xth Plenary Assembly, tests made in the United States of America indicated that keying of a superimposed pilot-frequency is a satisfactory method of identifying suppressed carrier single-sideband and independent-sideband emissions. The tests consisted of keying a pilot frequency of 250 Hz and superimposing the signal upon a 12A9J emission at a level of 18 dB below peak power. The lowest frequency of the emitted intelligence was 375 Hz. No difficulty was experienced in using standard communication receivers to receive the identifying signals. Studies are continuing to determine if the same technique can be applied to ionospheric scatter circuits.

Note. – With reduced-carrier emissions the above-mentioned method can only be applied if receivers without automatic frequency control are used.

REPORT 281-1 *

IDENTIFICATION OF SOURCES OF INTERFERENCE TO RADIO RECEPTION

(Question 15/VIII)

(1963 – 1966)

This Report shows the progress made, the methods used, and suggests future procedure, as noted in Docs. VIII/7, VIII/23 and VIII/30, Washington, 1962.

At the date of this Report, one can only give a partial answer to Question 15/VIII. Much work has been done, but the ultimate production of a chapter of the Handbook and its Annexes is complex (see Resolution 16-1. Chapter 14 and its Annexes should contain a collection of information such as photographs, magnetic-tape recordings, written descriptions, drawings, etc., describing the interference.) Uniform standards of measurement between the various countries have not yet been developed, and such standards are essential to make such information of international value.

The preparation of a chapter and its annexes of the Handbook should proceed in the following order of importance:

- information primarily for use at monitoring stations to aid in solving cases of internationally harmful interference;
- information to aid in identifying the sources of industrial interference.

The replies to Question 15/VIII, relating to television interference, have been quite adequate, although uniform standards of measurement and portrayal have not been developed.

Information on interference to television, obtained so far, has embraced interference caused by, or due to, the following:

- faulty adjustment of the television receiver,
- defects in television receivers,
- inherent design defects in the television receiver,

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* This Report was adopted unanimously.

- ignition interference,
- communication equipment,
- domestic electrical apparatus,
- devices with " break " contacts,
- Radar,
- receiver radiation,
- high voltage power lines,
- neon signs,
- lighting equipment,
- electro-medical devices,
- calculating machines and cash registers,
- multipath reception,
- video interference from aural emissions,
- high-frequency generators for industrial use.

There are many other specific cases that may be included in some of the broad categories above.

It has been pointed out, in some of the replies to Question 15/VIII, that the degree of distortion of the television picture resulting from the interference will vary slightly with the class or characteristic of the receiver, but the main features of the distortion are maintained. From this it may be assumed that the standards for the information collected on television interference need not be as rigid as the standards for information collected on interference to other services, such as those using the HF portion of the spectrum (3 to 30 MHz). This is because HF measuring equipment varies over wide limits in such characteristics as:

- bandwidth,
- selectivity characteristic,
- characteristics of oscilloscopes, spectroscopes and others.

The reply to Question 15/VIII, regarding information collected on interference in the HF range (3 to 30 MHz), that would be of use to monitoring stations, is not complete.

The procedures for preparing this information involve search of the literature and publications relating to interference, principally for the purpose of determining how the characteristics are described or illustrated (see Bibliography).

Reviews have been made of listed descriptions, illustrations, magnetic-tape recordings and films used by Administrations and private industry. Information from many professional engineering groups is being used in the study.

Some of the monitoring stations have made aural tape recordings, oscilloscope photographs, and written descriptions of individual characteristics of interference.

Account should be taken of C.I.S.P.R. work.

The need for such information of interference characteristics of radiations and uniform standards of measurement is urgent and is particularly desirable as aids to personnel at monitoring stations. Means must be found to publish such a catalogue.

To accelerate the assembly and publication of other information, Resolution 16-1 has been adopted.

The magnetic tape recording [18] already issued by the C.C.I.R. will form a complement to Chapter 14 of the Handbook (see Resolution 16-1).

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REPORT 282-1 *

INTERNATIONAL MONITORING FACILITIES

Reply to Recommendation No. 5 of the Administrative Radio Conference, Geneva, 1959

(Resolution 15)

(1963–1966)

With reference to Recommendation No. 5, adopted by the Administrative Radio Conference, Geneva, 1959, the I.F.R.B. has prepared a map (see Fig. 1), showing the distribution of monitoring stations throughout the world notified to the I.T.U. and participating in the international monitoring system, in the bands below 28 MHz.

For this purpose the world has been divided into 10 main areas, each divided into a number of sub-areas; the boundaries of the main areas are printed in heavy lines, while those of the sub-areas are shown by thinner lines, and correspond to the Geographical Zones for broadcasting given in the Annex to Appendix 1 of the Radio Regulations, Geneva, 1959. The numbers shown

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* This Report was adopted unanimously.

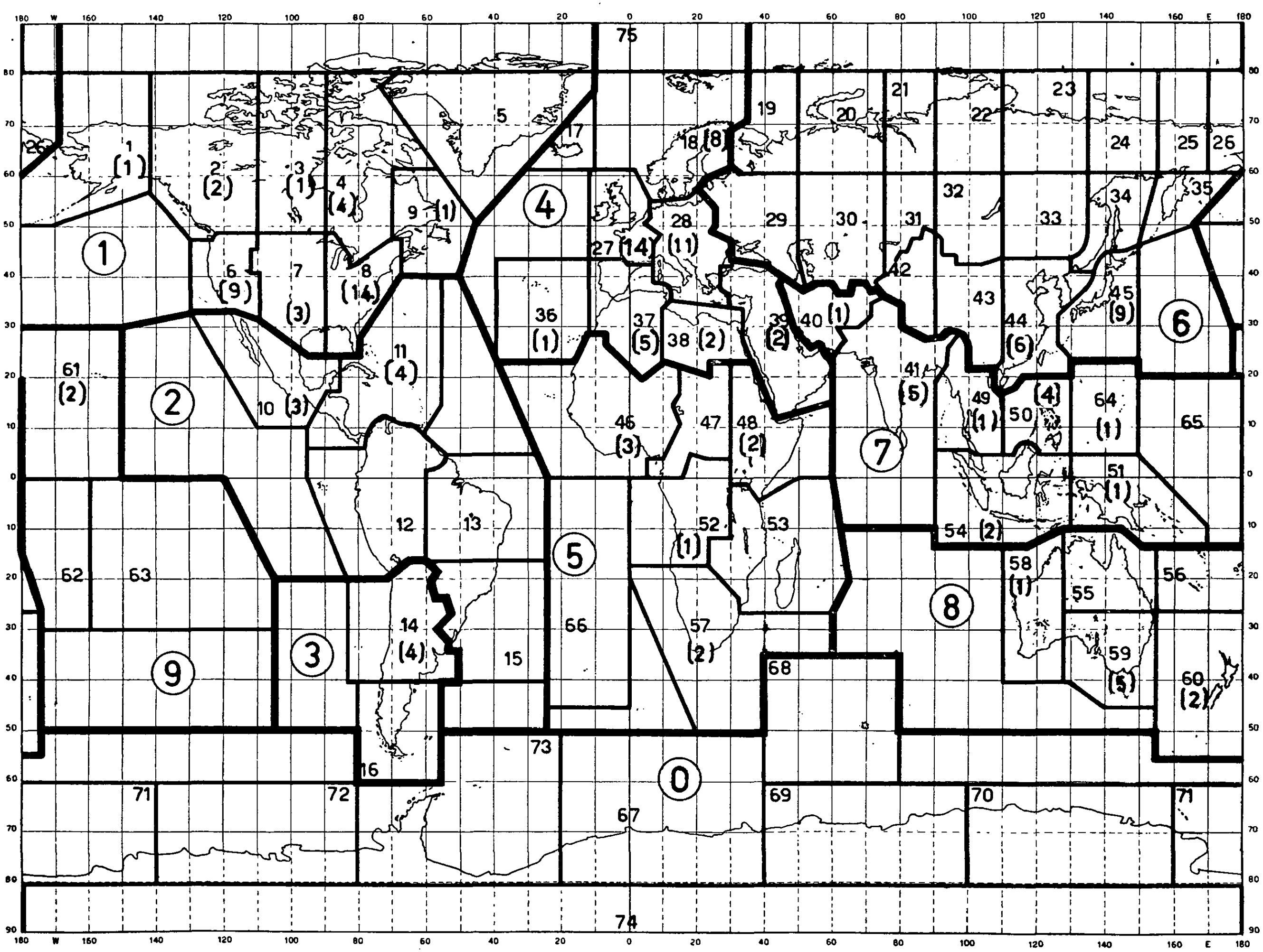
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FIGURE 1

inside circles on the map are the code numbers assigned to the various main areas, while the code numbering for the sub-areas is that used in the said Annex to Appendix 1 to the Radio Regulations, Geneva, 1959.

The numbers appearing between brackets on the map represent the number of monitoring stations notified to the I.T.U. for the sub-areas concerned, by the end of 1965.

Considering the practicality of establishing new monitoring stations, experience has indicated that Administrations will continue to locate and operate monitoring stations primarily to serve their own domestic needs and to fulfil their obligations under Nos. 675 and 676 of the Radio Regulations, Geneva, 1959. Cooperating Administrations will use part of the time of such stations, to make monitoring observations at the request of the I.F.R.B. and to furnish data on spectrum-occupancy for use by the I.F.R.B. Thus, from a practical viewpoint, it would appear that expansion of the international monitoring system to close present gaps in the world coverage depends almost entirely upon:

- establishment of monitoring facilities by countries having none at present but having the desire and domestic need for such facilities;
- expansion of the number of stations where a country has at present a system inadequate to meet its own needs;
- expansion of monitoring positions or other facilities at existing stations, or readjustment of work effort, to provide more data for the I.F.R.B.;
- co-operation in the international monitoring effort by Administrations having monitoring stations, but not yet furnishing spectrum-occupancy or other monitoring data to satisfy the requirements of the I.F.R.B.

Accordingly, it is suggested that the best approach to obtain expansion of international monitoring facilities to secure the desired results which prompted Recommendation No. 5, is for the Union and the I.F.R.B. to follow up §§ 1 and 2 of this Recommendation relating to the required efforts of Administrations, as envisaged in Article 13 of the Radio Regulations, Geneva, 1959.

REPORT 367 *

MONITORING OF SWEEPING-TYPE PULSE EMISSIONS

(Question 7/VIII)

(1966)

Question 7/VIII seeks information concerning the extent of interference caused by sweeping-type pulse transmissions, the preferred facilities and techniques for monitoring such emissions, and the method of identifying the source. Such transmissions are being used to sound the ionosphere:

- for purely scientific purposes;
- to determine existing propagation conditions, at times in connection with operational handling of communication traffic;
- to assist in the prediction of future conditions.

* This Report was adopted unanimously.

1. In evaluating the potentialities for interference of the various types of ionospheric sounder, it is convenient to divide them into two main categories, *vertical* and *oblique*, depending on the directional characteristics of the transmitting antenna.

1.1 Radiating systems of vertical-incidence sounders are normally designed to direct the energy vertically; however, scattering due to inhomogeneity of the reflecting media, plus radiation from the antenna at other than a vertical angle, may result in reception of the transmitted pulses at a considerable distance from the transmitter site.

1.2 Oblique sounders are often used in evaluating a transmission path at various frequencies, utilizing transmitting and receiving antennae the radiation patterns of which are essentially identical to the antennae used for handling communications over the path being studied (e.g. rhombic or log-periodic types). Since such antennae typically radiate an appreciable portion of the available energy at both horizontal and vertical angles which differ considerably from the desired direction, reception may take place over a wide area. Ionospheric scattering also contributes to the dispersion of the main beam, further increasing the interference potential of the emission.

1.3 One method of varying the frequency of the transmitter involves a continuous sweep in which the frequency is varied continually in repeated sweeps over a predetermined band of frequencies. The interference potential of the continuous-sweeping systems using high power transmitters has been found to be generally greater than for the more modern stepping systems, especially where the sweep rate is such that the emission is in the passband of the receiver for an appreciable period of time. Use of high-power systems of this type should be discouraged. An improvement over the continuous sweep technique is a method of gating a continuously variable oscillator to create a series of output pulses. This technique is currently being phased-out in the U.S.A. A third method involves a stepping technique in which one or more short pulses are transmitted on each of a series of frequencies spaced at appropriate intervals throughout the frequency range being studied. Research is continuing on new methods to accomplish ionospheric sounding.

1.4 Among the various types of sounder which use the stepping principle are those having the following emission characteristics:

System A

Frequency range: 1 to 49 MHz at 100 kHz intervals,
Total time per sweep: 8 min,
Pulse width: 25 μs,
Pulse repetition rate: 30 per second,
Number of pulses at each frequency: 30.

System B (The following is only one of a wide variety of operating modes of which this equipment is capable)

Frequency range: 4 to 64 MHz at intervals varying from 100 kHz at the lower end of the sweep to 400 kHz at the higher frequencies.
Total time per sweep: 16 s,
Pulse width: 1 μs,
Pulse repetition rate: 20 per second,
Number of pulses at each frequency: 2,
Scan rate: 1 sweep each 10 to 20 min.

1.5 A research institute in the United States, which has operated a large network of oblique sounders during the past three years, reports that interference resulting from its ionospheric sounders has a negligible effect on radiotelegraphy or facsimile services, provided that the receiving terminals for these services are beyond the limits of the ground-wave transmission from the sounder transmitter. For those receivers within range of the ground-wave, it is necessary to consider the characteristics of the receivers to determine the degree of interference which may result. Sky-wave interference to radiotelephony is also reported to be negligible except when the sounder transmitters radiate a significant number of pulses on the same frequency during one scan.

2. The best technique for monitoring transmissions from the various types of sounder would be by making use of the appropriate sounder receiver. However, to provide one of each type at a monitoring station would entail a large expenditure of money. Therefore, it is evident that other methods of monitoring these transmissions by stations in the international monitoring system must be used.

Some limited success has been achieved by monitoring stations in the U.S.A. in identifying oblique ionospheric sounders when provided with information concerning the emission characteristics and the transmission schedule or programme. Equipment used includes a suitable receiver, an oscilloscope and an accurate time source. Since it is common practice to programme the sounder operation so that the sweep is started on the hour and at regular intervals thereafter (5, 10, 15 etc. min), transmissions from more than one sounder may be observed at a particular frequency at approximately the same time. It is therefore necessary to be able to measure the time of reception of the pulses quite precisely. This can be done by comparing the received pulses with local timing pulses on an oscilloscope. The pulse repetition rate may likewise be determined by oscilloscope observations, provided two or more pulses are radiated at each frequency. A spectrum analyser may also be a useful aid in determining the emission characteristics. Measurement of the pulse length, especially where short pulses are involved, presents a problem because of the need to use a relatively selective receiver, resulting in considerable pulse distortion, as observed on the monitoring equipment. Although direction-finders or rotable directional antennae may be useful in obtaining an approximation of the azimuth of arrival of the transmission, by observing several consecutive sweeps with the direction-finder or antenna adjusted for a different direction for each sweep, this is a time-consuming procedure, especially where the signal is subject to fading.

3. As is mentioned in § 2, identification of sounder transmissions as a source of interference depends upon availability of information concerning the emission characteristics and the transmission schedule or programme of the particular sounder concerned. However, if some means could be devised whereby an identifying signal could be incorporated into the transmissions without increasing the interference potential, the problem of positive and prompt identification would be greatly alleviated. Such identification would in many cases be a definite aid in monitoring of swept emissions, but it would not eliminate the need for information concerning the characteristics and location of all sweeping-type transmitters and their transmission schedules. Publication of this information should be on an international basis.

REPORT 368 *

EXPEDITIOUS METHOD OF DETERMINING FIELD STRENGTH AT MONITORING STATIONS

(Question 4/VIII)

(1966)

Question 4/VIII seeks information on an expeditious method for determining field strength in the International Monitoring system, details of equipment for suitable application, and details of operation and accuracy of measurement.

* This Report was adopted unanimously.

Information on this subject is contained in Docs. VIII/12 (U.S.A.), VIII/15 (United Kingdom), VIII/16 (Portugal) and VIII/18 (Japan), 1963–1966. The information may be summarized as follows:

1. General

A given field strength will produce different levels of signal at the output of the receiver, depending upon the characteristics of the antenna and the receiver. For example, a signal rated by the observer as QSA-1, because it is " scarcely perceptible " (Appendix 13, Radio Regulations, Geneva, 1959) as received on a non-directional antenna of short effective length and a receiver of poor sensitivity and high noise figure, might produce a " fairly good " signal with a highly-directional, high-gain antenna and a better receiver. It could appear misleading on the basis of the QSA scale and SINPO, SINPFEMO-codes to rate the signal as received in the latter case as less than QSA-3.

The degree of accuracy obtainable depends upon several factors, including freedom of the antenna site from local conditions which disturb the arriving wavefront (e.g., local reflection or reradiation), the care taken in calibrating the systems and the skill of the operator in evaluating the results. Since, in the interest of expeditious measurements, some compromise with optimum accuracy may be required, the $\pm$ 2 dB accuracy given in Recommendation 378-1 may not readily be achievable. Under conditions typical of the installations used at monitoring stations, the instant field strength will usually be within $\pm$ 6 dB of the actual field strength of the vertically polarized component (see the Annex to Recommendation 378-1, § 1.1.1). Where greater accuracy is required, information contained in Report 227 and the Annex to Recommendation 378-1 should be taken into consideration.

2. System and accuracy of measurement

2.1 One suitable system, described in Doc. VIII/18 (Japan) is shown in Fig. 1 and consists of an antenna with a known antenna gain, a receiver with a detection output meter, a noise generator and a variable HF attenuator.

2.2 An output from the noise generator at a known level N dB is applied to the receiver, and the gain in the receiver is regulated so as to keep the detection output meter at a certain value. Then the signals to be measured are received by the antenna of known antenna-gain K dB and are applied to the receiver through the attenuator in the same condition as mentioned above. The attenuator is adjusted so that the detection output is equal to the previous value; the value is read A dB, and then the field-strength E dB is calculated from:

$$E = N + A - K \qquad \text{(dB)}$$

If the scale of the attenuator is graduated directly in units of $(N + A - K)$ dB, the relative gain difference of the antenna used is within 5 dB over the frequency range 2 MHz to 20 MHz. Therefore, taking into account errors due to other causes, the field-strength can be read directly on the scale of the attenuator with an accuracy within $\pm$ 5 dB. For other frequencies, calibration curves may be used, and the field-strength can be determined from the above equation, the error being maintained within $\pm$ 5 dB.

2.3 For determining the field strength of keyed telegraph signals, it is preferable that an oscilloscope be used instead of a meter; this is because the readings of a meter in response to keyed signals are inaccurate and are dependent on the time characteristics of the particular meter used.

3. Features of the system

3.1 The output of the noise generator used as a calibrating source is constant and independent of frequency for the stated frequency range. Therefore, over this frequency band there is no need to re-tune the receiver each time, thus enabling calibration of the receiver with ease.

3.2 If the receiver has enough sensitivity for the output of the noise generator, no account need be taken of linearity, or the frequency characteristic, etc. (however, the receiver should be used below the saturation point, and a detection output meter is needed).

3.3 As the antenna used has a high gain, the minimum field-strength which can be measured is low.

4. Desired characteristics of elements used

4.1 *Receiver*

A receiver as generally used for monitoring will serve for the purpose. It is desirable to use a detection output meter and the best possible noise figure.

4.2 *Noise generator*

It uses a diode-generating circuit and its output is independent of the frequency. If the output is low, some amplification is needed, and the amplification characteristic must be broadband.

4.3 *Antenna*

The requirements of the antenna are: non-directivity, broadband, high gain and simplicity of construction. In general, a vertical non-directional loaded antenna is considered most desirable.

By using an inverted cone antenna as described in Doc. VIII/15, the equipment may be used over a very wide frequency band, say 12 kHz to 27·5 MHz. The initial calibration, to give an overall accuracy of measurement of field strength of $\pm$ 6 dB, might be done by calculation from the geometry of the antenna (see Report 373, Figs. 4 to 8).

4.4 *Attenuator*

It must have a good frequency characteristic over the frequency band in use.

5. A more rapid method is described in Doc. VIII/16 (Portugal) as follows:

If a lesser degree of accuracy could be accepted, a short vertical omnidirectional antenna could be installed near the antenna system of the station. This antenna would certainly be affected by the proximity of directional and other antennae at the monitoring station, but it should be placed sufficiently near to the station building to be connected to the receivers by coaxial cable.

The antenna, about 5 m high, is installed with an earthing system consisting of star-shaped conductors buried in the ground and connected by a transformer to a coaxial cable, which in turn can be connected to any of the operators' positions.

Each working position, with its receiver or receivers, is equipped with a coaxial switch, by means of which the operator can select the most appropriate antenna in the normal system (directional or otherwise) for monitoring. One position of the switch permits his receiver to be connected to the vertical antenna.

The vertical antenna-receiver unit is so calibrated that it can be used, in conjunction with the receiver measuring apparatus, as a secondary system for measuring field-strength.

Thus, if an operator listening to an emission on one of the normal antennae wishes to know the approximate field-strength, he simply operates the coaxial switch to connect his receiver to the vertical antenna. The reading on the receiver measuring apparatus and the frequency calibration curve of the receiver immediately give the approximate field-strength.

If a more accurate figure is required, the d.c. voltage can be recorded after detection in the receiver and the mean value determined.

With this kind of equipment, an accuracy of about ± 6 dB is possible.

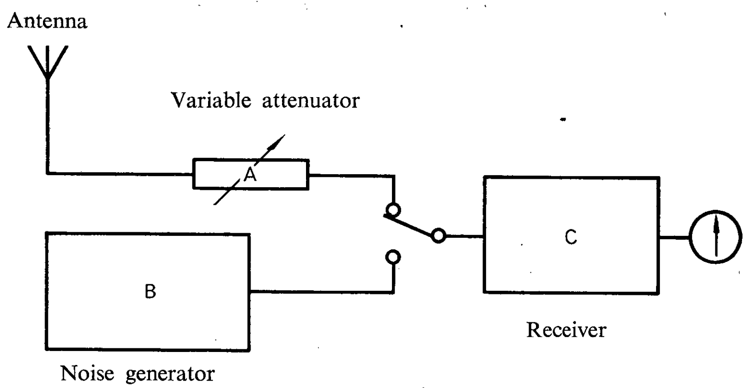

FIGURE 1

Arrangements for test

REPORT 369 *

MEASUREMENT OF FREQUENCIES OF SINGLE-SIDEBAND, INDEPENDENT-SIDEBAND AND OTHER COMPLEX EMISSIONS

(Question 2/VIII)

(1966)

This Report summarizes the contributions and discussions in response to Question 2/VIII which provide only partial solution to the problems encountered in the measurement of frequencies of transmissions of certain complex classes of emission:

1. Determination of the centre frequency of complex emissions, where the spectrum of the emission is unknown, presents a difficult problem, particularly when a signal is encountered which has no discrete carrier and where all the tones of the system (in the case of a multi-tone system) are not being transmitted. From the point of view of the monitoring stations, the measurement of independent-sideband (ISB) and single-sideband (SSB) emissions would be facilitated if a carrier were transmitted, but this is often not practicable when considering the requirements of many present-day systems.

In many ISB emissions a prior knowledge of the system can give guidance in locating the carrier frequency, so facilitating assessment of the centre frequency. This emphasizes the need for all transmissions to be clearly described when notifying assignments. Particularly difficult cases are ISB emissions employing two-tone or frequency-shift sub-carriers, since they may be indistinguishable from pure F1 emissions. To facilitate the measurement of the more complex classes of emission, some operating organizations have adopted designation systems which identify separately the sidebands and sub-carriers. Similarly,

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* This Report was adopted unanimously.

a system of designation may be used to indicate the position of the centre frequency with respect to the assigned frequency.

2. In those instances where a characteristic frequency (defined in No. 86, of the Radio Regulations, Geneva, 1959) has been established, e.g. a reduced or incompletely suppressed carrier or a pilot frequency (see § 2.2.2 of Recommendation 379-1), it is often convenient to measure the characteristic frequency by adjusting the frequency of a stable variable radio-frequency oscillator to coincide as exactly as possible with the characteristic frequency as observed on a spectrum analyser of high resolving power. The precise frequency of the radio-frequency oscillator may then be determined by the usual methods and the deviation from the assigned frequency calculated. Using this procedure for measurements in band 7 (3–30 MHz), it is desirable that the spectrum analyser have a maximum resolving power (see Recommendation 182-1, § 2), at reduced sweeps, of 10 Hz and that the short-time (10 s) stability of the variable radio-frequency oscillator be 5 parts in 10^7 or better.

3. Doc. VIII/78 (Japan), 1963–1966, describes a method of determining the approximate frequency of the suppressed carrier of A3J emissions, by measuring the frequency of the receiver demodulating oscillator when the oscillator is adjusted for optimum speech articulation and understandability. According to tests conducted under varying conditions of signal level and noise, the accuracy of this method in the HF band in many cases may be within 30 Hz.

4. In multi-tone transmissions, where the characteristics of the emission are known, determination of the relationships between the various components of the emission with a spectrum analyser and a variable frequency oscillator to serve as a reference frequency, may permit a reasonably accurate determination of the centre frequency. Another similar method is to photograph the spectrum display, together with known frequency markers.

REPORT 370 *

TYPES AND METHODS OF ASSISTANCE BY MONITORING STATIONS TO THE OPERATION OF VARIOUS RADIO SERVICES

Exchange of technical information between receiving and measuring stations by means of exchanges of staff

(Study Programme 13A/VIII)

(1966)

This Report takes account of Doc. VIII/79 (E.B.U.), 1963–1966, submitted to the XIth Plenary Assembly of the C.C.I.R., Oslo, 1966.

To provide for liaison between the various receiving and measuring stations exploited by its members, the European Broadcasting Union arranges periodical meetings of the engineers-in-charge of those stations. The engineers-in-charge have expressed the opinion that, to improve the cooperation between the receiving stations and to keep each other informed of the methods and equipment used in the other stations, it would be useful to arrange exchanges of staff between them. Such exchanges were therefore arranged in 1963 and 1964 under the auspices of the E.B.U., between three receiving stations. The six operators who took part in this scheme were all qualified technicians having a considerable number of years of experience.

After these exchanges, the engineers-in-charge of the three stations in question submitted reports on the project, indicating the benefits that had accrued. They also discussed

* This Report was adopted unanimously.

the project at a meeting of the engineers-in-charge of receiving stations exploited by the E.B.U. and its members, in January, 1966.

The detached operators in each case took over the work of operators on the staff of the station to which they were attached. Consequently, they were fully integrated in the " life " of that station and worked under exactly the same conditions as the other operators there. They very quickly became accustomed to their new work and although language difficulties were occasionally encountered, they were never particularly serious.

The engineers-in-charge concerned are of the opinion that a substantial benefit was gained by these exchanges, because:

- the detached operators had the time to inform themselves thoroughly regarding the organization and equipment of the other station, and to compare them with those of their own stations. Each of the three stations now has at its disposal more complete information about the equipment used at the other stations and it is therefore possible for a valid comparison to be made with its own corresponding apparatus. The operators were also able to appreciate certain technical operations which would lead to a higher efficiency and to exchange practical suggestions;
- an atmosphere of reciprocal confidence was created between the staff of each station and their foreign colleagues who were attached, which has led to much closer collaboration between the stations. There has resulted an improvement in the regularity and rapidity of the exchange of information, which has improved the efficacity of the monitoring effected by the three stations. This, in turn, has proved beneficial when difficulties have been experienced in identifying transmission;
- these exchanges encouraged personal contacts between operators from different countries having different customs and they have also given them a greater interest in their work. The attached operators certainly showed a great deal of interest and put many questions to their colleagues regarding the work, working conditions and methods, training and the like.

It would seem that the optimum duration for such exchanges is two or three weeks. In effect, the attached operators must be given time to accustom themselves to new apparatus and methods, and about ten days seems to be the absolute minimum for participating in all the operational duties which are included in a shift, as this implies working at all the various operating positions.

It would seem also that the staff which draws the greatest profit from the exchanges are those of the greatest seniority and experience, but the younger operators nevertheless show much interest in them. In order that an operator may draw the greatest benefit from the attachment, it is necessary that he be assigned tasks which are not too different from those that he undertakes in his own station.

The engineers-in-charge of the stations taking part in this project organized by the E.B.U. deem that it should be repeated at intervals.

REPORT 371 *

MONITORING SERVICES IN THE NEW AND DEVELOPING COUNTRIES

(Question 12/VIII)

(1966)

1. Introduction

Question 12/VIII seeks to discover what kind of monitoring services should be started by new and developing countries, the guidance that can be given in the establishment and organization of such services and the facilities to be provided by monitoring equipment, including suitable characteristics.

* This Report was adopted unanimously.

2. Tasks which a monitoring station should be able to perform

2.1 *Selection of frequencies for new communication channels*

Studies should be made over a sufficiently long period, of the use of the radio-frequency spectrum in the selected band with a view to choosing frequencies which can be used without causing interference to other already authorized services.

This operation is most important for Administrations and private operating agencies, since the quality of the circuit and the extent to which it is free from operational incidents depend to a large degree on the care with which the operating frequencies have been chosen.

2.2 *Monitoring of emissions*

By this is meant the monitoring, either periodically or whenever a check seems required, of the country's own transmitters, and, if necessary, of those of their correspondents. This monitoring consists in:

- measuring the frequencies and bandwidths of the emissions;
- checking the quality of the modulation;
- checking for freedom from spurious emissions and, in some cases, measuring the strength of the radiated field.

2.3 *Measures relating to interference*

In all cases of interference affecting a circuit, measures should be taken promptly to:

- determine the cause of interference,
- identify the interfering emission,
- determine the technical characteristics of the interfering emission,
- propose steps for eliminating the interference.

2.4 *Participation in the international monitoring system*

In addition to the help which it should be able to give to another country or another monitoring station within the framework of §§ 2.1, 2.2 and 2.3, a monitoring station must also be able to participate in the international monitoring system under the conditions specified in Article 13 of the Radio Regulations, Geneva, 1959.

Such participation consists in carrying out all the monitoring of operations requested by the International Frequency Registration Board (I.F.R.B.).

3. Organization and operation of a monitoring station

3.1 *General*

As regards the organization of a monitoring service, there is no existing plan to meet all needs. A service might, for instance, be envisaged consisting of a number of organic sections each playing a specific part. This is why, when planning the structure of a monitoring service the nature of the duty or duties to be provided should first be determined. Among the relevant factors, one might mention the frequency bands to be monitored, the geographical extent of the area covered, the advisability of installing long-range direction-finders and the need to provide mobile monitoring facilities to supplement the fixed installations. All these factors should be taken into account when determining the number of stations required and to obtain an idea of the areas where they should be set up. It goes without saying that these planning tasks entail budgetary considerations, both as regards staff and equipment, and it is often these considerations, rather than the requirements themselves, that determine the scope of the future service. In such cases, thorough preliminary study of all the factors involved will enable the best use to be made of available funds.

3.2 *The choice of site for the monitoring station*

The site of a monitoring station must be easily accessible by road, easily connected to essential public services such as power and water supplies, as well as telephone communications and should be near to a residential area where the staff can live. At the same time, the site selected must be far enough away from built-up areas to avoid industrial interference. The interference range of a residential area is approximately 400 m and that of an industrial zone approximately 5 km. For HF monitoring, the height of the terrain is of no importance, but since most monitoring stations operate also in the VHF and UHF bands, it is better to choose a site higher than the surrounding ground. As a general rule, it is also better to site the station on flat-land covering an area of approximately 100 000 m^2, with good conductivity and with no obstacles within a radius of approximately 5 km. When planning the establishment of MF and HF direction-finders, a larger area should be envisaged.

Assuming that the developing country in question starts off with the very minimum of communication equipment, and probably no monitoring facilities at all, the monitoring installations might quite easily be combined with the receiving station of the communications installations, at least during the initial period of operation. Each transmitting station should be capable of measuring its own frequencies, to be able to operate correctly. Each receiving station might be likewise equipped, so as to be able, if necessary, to render assistance to its counterpart transmitting station, in measuring the interfering signals and to carry out reciprocal monitoring of the frequencies of its correspondents. Besides resulting in a saving of staff (the same engineers and technicians being available for both communications and monitoring operations), performance of these various functions in conjunction would save the expense of establishing the monitoring station on separate ground and in separate premises. Moreover, the various antennae of the receiving station would be of the greatest assistance to monitoring operations.

Obviously, in countries where the receiving stations are operated by private operating agencies other than the national Administration, the question of establishing a monitoring station in a receiving station should be examined jointly by the Administration of the country and the private agency operating the receiving station.

3.3 *Buildings and power supply*

The group of installations of a self-sufficient monitoring station must be housed in premises with a floor space of at least 70 m^2 consisting chiefly of an equipment room, a power room and an office.

The centre's power consumption can be estimated from a few to several kilowatts, depending on the equipment used.

It is useful to have a stand-by generating set, although some of the equipment may operate from batteries.

In the proximity of the station, connection to the power supply must be by underground cable, as an overhead line is likely to cause interference and may be an awkward obstacle in the neighbourhood of the station's antennae.

3.4 *Antennae*

The question of the antennae for the equipment of monitoring stations is dealt with in Report 373.

3.5 *Staff*

3.5.1 *Establishment*

The following staff is absolutely essential for proper working of the monitoring station:

– a specialist in charge of the station,

- four operators, capable of performing the more common operations and working shifts so that one of them is always on duty,
- a good all-round technician, responsible for new developments, maintenance and fault clearance and also capable of working as an operator.

3.5.2 *Recruitment and training*

Although no precise rules can be laid down here on these points, the problem is worth mentioning, as it is undoubtedly the most difficult to solve.

The staff of a monitoring station must be fully familiar with both the technique and the operation of the various services which use the frequencies monitored.

Its members must therefore be young enough to be able to keep abreast of the latest developments in radio technique, but nevertheless have a sound experience of the work done in transmitting or receiving centres or the radio-operating centres of the fixed, mobile and broadcasting services. Such experience would seem to be obtainable only through long periods of practical work in these various services.

The assistance and guidance to be given to Administrations for the purpose of establishing and organizing a monitoring service may take various forms, such as:

- consultation with officials of successfully-operating monitoring services;
- training periods in operative monitoring services;
- vocational training programmes, conducted under technical assistance procedures, for the key personnel of Administrations proposing to establish a monitoring service;
- review of the many technical documents dealing with monitoring rules and standards published by the I.T.U., engineering or trade organizations and Administrations; study of textbooks and equipment instruction-manuals and any other relevant explanatory material.

4. Technical equipment

4.1 *Basic requirements*

Although some degree of monitoring coverage would be possible with even the simplest and most inexpensive installation (e.g., a receiver and a suitable antenna), the following might be considered as a basic monitoring installation which will satisfy the requirements for the more important monitoring functions.

4.1.1 *Receivers*

Receivers covering a minimum frequency range from 200 kHz to 30 MHz with additional coverage are required. In selecting the receivers, the various classes of emission to be monitored (for example, single-sideband telephony) should be taken into account and provision made for the reception of such emissions. A number of degrees of selectivity, from 1 kHz or even a much smaller bandwidth to at least 12 kHz at the 40 dB points on the receiver selectivity curve, are also desirable.

At frequencies up to 30 MHz, all the qualities expected of receivers for main receiving stations are required of monitoring receivers, with the addition of good frequency setting accuracy (better than 500 Hz for communication receivers and better than 1 kHz for broadcast receivers), rapid tuning and a minimum of waveband switching. Special attention needs to be given to the suppression of receiver oscillator radiation and to the suppression of spurious responses of the receiver. A panoramic adaptor unit may be used with a receiver to provide a visual display of spectrum occupancy. There is also considerable advantage in using single-or independent-sideband receivers when receiving double-sideband signals in the presence of interference.

Above 30 MHz, receivers capable of accepting amplitude- and frequency-modulation emissions are essential and it is important to ensure that adequate bandwidth is available.

All receivers should be provided with outputs of the intermediate frequency at low impedance and with radio-frequency injection inputs. If the latter are located between the radio-frequency and frequency-changer stages, test and reference signals injected into receivers, usually at low level, will not radiate from the receiving antenna. Again, all radio-frequency and intermediate-frequency access points should have a common value of impedance, ideally the same as that of the antenna input impedance.

4.1.2 *Frequency measuring equipment*

As stated in the considerings of Recommendation 377-1, it is desirable that the error of frequency measurement shall not exceed one-tenth of the frequency tolerances specified in Appendix 3 to the Radio Regulations, Geneva, 1959. The most stringent internationally agreed tolerances refer to broadcasting stations and fixed stations operating in the band 4 to 29·7 MHz. This tolerance is 30 parts in 10^6, reducing to 15 parts in 10^6 for new transmitters after 1 January 1964, and for all transmitters after 1 January 1966. The corresponding measuring equipment therefore need to determine frequency to an accuracy of 3 parts in 10^6 and 1·5 parts in 10^6 respectively, or better.

Crystal oscillator frequency standards, with stabilities better than 1 part in 10^9 per day, are available and, to maintain this order of stability, continuity of power supplies must be assured. This can be facilitated by using transistorized frequency standards which can be operated by a battery or by a mains power supply. Frequency standards are usually calibrated by reference to standard time and/or frequency transmissions, now available in a number of countries. Many of these transmissions have stabilities at the transmitter of better than 5 parts in 10^9, and calibration errors of less than 1 part in 10^8 are easily realized by the use of a chronograph or frequency comparison apparatus (see § 4.1.6). Where these transmissions are not available, the cooperation of another monitoring station could be sought to make simultaneous measurements on one or more known stable HF transmissions.

Two basic systems of frequency measurement are described below. The first system uses a direct-reading decade oscillator or synthesizer, which may be locked to the nearest multiple of, for instance, 100 Hz by the local frequency standard, set to give any output frequency between 20 Hz and 30 MHz, frequencies between 100 Hz points being generated by a variable-frequency oscillator. Harmonic amplifiers may be used to extend the range up to 1000 MHz or higher. In measuring AM signals, or any signal having discrete components, the receiver is first tuned to the wanted signal. The decade oscillator or synthesizer output is then adjusted so that the beat between the signal and synthesizer frequencies is exactly 1 kHz. This difference frequency is determined by a Lissajous figure on a cathode-ray tube. The frequency of the signal can be read off the decade dials of the synthesizer plus or minus 1 kHz, depending on whether the reference signal is set below or above the signal frequency. In the second system, developed for use principally in the HF band, the principle involved is to lock the first oscillator of a receiver incorporating automatic frequency control, to the signal component to be measured and then to measure the first oscillator frequency on a decade counter. The frequency of the signal is then the count frequency, plus or minus the intermediate-frequency of the receiver, depending on whether the oscillator is above or below signal frequency. The first system has the advantage of higher accuracy while the second system is less useful for weak signals but has the advantage of speed of measurement.

When measuring frequency-modulation signals, a difficulty arises owing to the reduction in carrier level during modulation. By using a mid-frequency indicator to show differences between the mid-frequency of the frequency-modulation spectrum and the reference frequency, signals with deviations up to $\pm$ 100 kHz or even higher can be measured. For additional details on frequency measurements see Recommendation 377-1 and Report 272-1.

4.1.3 *Bandwidth or spectrum measuring equipment*

Bandwidth or spectrum measurements may be made using a spectrum analyser. The performance of all types of instrument for bandwidth measurements is limited by fading and interference especially for observations on long-distance transmissions. With a spectrum analyser it is possible, by photographically superimposing the results of several successive sweeps, to obtain very useful information on the bandspread of most transmissions received at monitoring stations. Report 275–1 describes typical spectrum analyses. For bandwidth measurements see Recommendation 443 and Report 275–1.

4.1.4 *Field-strength measuring equipment*

Many equipments for field-strength measurements in the frequency range 150 kHz to 30 MHz incorporate loop antennae connected to the input of a receiver. Such equipment is usually capable of an accuracy of $\pm$ 2 dB, but does not necessarily have sufficient sensitivity. An alternative arrangement giving greater sensitivity is to use a vertical rod antenna shorter than 1/4 wavelength for the highest frequency to be measured, feeding directly into a low–noise amplifier. The system is calibrated by injecting a known voltage in series with the antenna. It is necessary to erect the antenna clear of large buildings and possible sources of interference. If the field-strength measuring equipment is not situated close to the antenna, the low-noise amplifier may be located in a watertight box at the base of the antenna, the output of the amplifier and the antenna calibrating signals being sent over two coaxial cables.

Field-strength measurements in the VHF band may be made by erecting dipole antennae, of dimensions appropriate for the frequency to be measured, at a height of about 10 m above ground. The receiver input voltage may then be determined by substitution, the field strength for the matched condition being calculated by the equation:

$$\text{Field strength} = \pi/\lambda \text{ (source e.m.f.)}$$

For details of field-strength measurement techniques, see Recommendation 377–1 and Report 273–1, for details of simple and expeditious methods of measuring field strength, see Report 368 and Recommendation 442.

4.1.5 *Identification equipment*

The identification of radio signals is one of the most difficult tasks laid upon a monitoring station. This difficulty is partly due to the infrequent transmission of identifying signals and partly to the use of abbreviated call signs. In the case of complex telegraph systems there is difficulty both in radiation and in monitoring and decoding identifying signals.

The facilities referred to above, namely direction-finding, frequency measurement, spectrum analysis and field-strength measurement, may all be used as contributory factors in the identification of the emission, particularly when their precise frequency and emission characteristics have been notified internationally. It is also desirable that a monitoring station be equipped for the reception of ISB and FSK signals, in addition to receivers for classes of emission A1, A2 and A3, together with means of recovering from radiotelephony privacy systems, and with some of the simpler telegraph instruments such as undulators and variable speed teleprinters. A magnetic tape recorder is also valuable for recording the more abstruse emissions for reference and subsequent examination by an authority familiar with more complex types of transmission system (see also Recommendation 379–1 and Report 280–1).

4.1.6 *Cathode-ray oscilloscope*

A cathode-ray oscilloscope having a vertical amplifier with adequate frequency response to permit direct display of the intermediate-frequency output of the HF receiver normally used for observations of A3 emissions. This oscilloscope will provide a convenient means of observing broadcast station modulation levels as well as for frequency matching (see § 4.1.2 above) and for observing the waveform of keyed emissions (A1, F1, etc).

4.2 *Additional equipment*

Although equipment mentioned in § 4.1 will perform many of the monitoring functions, certain additional instruments will permit more effective operation of a monitoring station and will expand its capabilities. These facilities include:

4.2.1 Direction finders for localizing sources of interference to a particular area and as an aid in identifying emission sources based upon knowledge of their location. Generally, only the larger monitoring systems, having a minimum of three direction-finding stations, will benefit greatly from fixed direction-finders, since a minimum of three bearings are needed to obtain a reasonably accurate fix. However, even one or two direction finders will provide some useful information. Where the direction-finder networks of two or more Administrations can be coordinated so that the bearing data obtained may be shared, improved fix accuracy should result in many instances. For detailed information concerning the characteristics and relative merits of various types of direction finder, see Report 372.

4.2.2 Automatic monitoring equipment for unattended surveillance of selected portions of the radio-frequency spectrum to provide a permanent record of channel occupancy in terms of time, approximate signal level and bandwidth, and other useful information. For additional details, see Report 278–1.

4.2.3 Visual monitoring equipment. Although spectrum analysers will provide displays of limited areas of the radio-frequency spectrum, their design is directed primarily toward permitting a detailed analysis of an emission, rather than to display a wide area of the radio-frequency spectrum in terms of presence or absence of emission. Instruments designed especially for visual monitoring purposes usually make use of large cathode-ray tubes, to give a reasonably detailed display even where a large area of the radio-frequency spectrum is under observation. Sweep rates are usually sufficiently fast so that an essentially continuous display is achieved, as contrasted to the slower sweeps which are employed in spectrum analysers to obtain optimum trace resolution. Visual monitoring equipment and techniques are discussed in greater detail in Report 279.

4.2.4 With the aid of a suitable device, frequencies below 3 MHz can be transposed within the frequency range covered by the HF equipment described. In this way, the possibilities which this equipment offers and with which we have already dealt, can be exploited to the full.

4.2.5 Adapters are available to enable double-sideband receivers to be used for the reception of single-sideband and independent-sideband transmissions.

4.2.6 Apparatus is available for the automatic comparison and control of a frequency source, relative to a VLF standard-frequency transmission. (A list of standard-frequency transmissions is contained in Report 267–1).

4.2.7 Monitoring of frequencies above 30 MHz generally calls for mobile equipment on motor vehicles. This could comprise:

- a suitable receiver (possibly of the panoramic analysis type),
- a frequency measuring device, capable of acting as a calibrated generator with an accuracy appropriate for the emission to be measured (see Recommendation 377–1),
- a field-strength measurer, covering up to 1000 MHz,
- a spectrum analyser, with which a single emission or several adjacent emissions with frequency shift may be observed, while a calibration, based on the calibrated generator, offers the possibility of measuring the nominal frequency, actual occupied bandwidth, frequency variation, etc.
- an array of antennae, suitable for the type of monitoring to be effected.

5. Doc. VIII/80 (E.B.U.), period 1963-1966

The European Broadcasting Union has published a Technical Monograph (No. 3102)* entitled: " Receiving and measuring stations for broadcasting purposes ", which describes the various measuring methods and apparatus used in several European monitoring stations. In this monograph, a number of passages describe the techniques and equipment likely to be of particular interest to new and developing countries; in particular, the following paragraphs should be mentioned:

Chapter III: Measuring methods

1. The verification and comparison of the frequencies of the standards
2.2 Frequency measurement by the double-beat method
2.3 Frequency measurement by the interpolation method
2.6 Special cases of frequency measurement
3. The determination of the occupation of the frequency spectrum
4.1 Field-strength measurement procedure
6. Measurement of the depth of modulation

Chapter IV: Apparatus required

1. Antennae
2. Receivers
3. Frequency standards
4.1 Constitution of a frequency-measuring position
5.1 Constitution of the automatic recorders of the occupation of the spectrum
6.1 Constitution of the field-strength measuring equipment
6.2 Essential characteristics of field-strength measuring sets
8.1 Device for measuring the average depth of modulation.

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* This monograph can be obtained from: Centre technique de l'U.E.R., 32 Avenue Albert-Lancaster, Bruxelles 18.

REPORT 372 *

DIRECTION-FINDING AT MONITORING STATIONS

(Question 8/VIII)

(1966)

Study Group VIII, taking account of Doc. VIII/34 (U.S.A.) and VIII/87 (India) 1963–1966, furnishes:

- information concerning fixed monitoring stations;
- information concerning mobile monitoring stations;
- a summary of information contained in the various documents, which, without being new, will be useful, when grouped, to the monitoring stations;
- this information concerns the accuracy of bearings and positions.

1. Fixed direction-finders (see Annex)

Methods of direction finding and procedures for improving the accuracy of bearings at fixed monitoring stations are generally directed towards producing an acceptable degree of accuracy on waves propagated via the ionosphere. Ionospheric propagation exerts pronounced effects on the characteristics of radio waves which seriously affect the results obtainable with the different methods of direction finding. The simple rotatable or crossed loop method of direction finding on ionospheric waves fails at the outset to meet the requirements of accuracy and consequently need not be considered. Since sky-waves throughout the entire HF range are of primary importance in direction finding associated with international monitoring, we may also disregard methods that are limited to either very narrow ranges of frequencies or to frequencies lying above the HF spectrum. Considering also that it may often be necessary to locate unidentified sources of interference or unauthorized transmitters, we may dismiss from discussion those methods of direction finding which depend upon the control or cooperation of the transmitter whose location we are trying to determine. The methods that have proved useful for long-range HF direction finding are discussed briefly below:

1.1 *Spaced-loop system*

Spaced loops have proved useful in producing bearings, particularly over the shorter distance ranges of up to about 650 km (400 miles). The usual construction consists basically of two vertical, parallel loops rigidly mounted coaxially at the ends of a horizontal, rotatable boom. Another type consists of two such pairs perpendicular to each other in fixed position, with transmission lines feeding a goniometer at the centre.

In the fixed, four-element system there is an octantal error (in addition to any residual error in the goniometer), due to the spacing of the elements being an appreciable fraction of a wavelength at the high-frequency end of its working range. However, allowance can be made for this error in a calibration chart.

In a coaxial spaced-loop direction-finder the pickup elements (antennae) are closed loops and their individual e.m.f.'s do not vary with the angle of incidence in the vertical plane. Thus, the proportion of wanted (vertically polarized components) pickup to unwanted

* This Report was adopted unanimously.

(horizontally polarized components) remains high. Since the loops are connected in opposition, the net polarization error is at a minimum, and this system is superior to the Adcock up to about 650 km (400 miles). Performance is very good even where the vertical angle of the received wave exceeds 45°. The sensitivity is almost 20 dB poorer than a single loop of the same size as one of the spaced loops.

1.2 *Adcock*

The Adcock is characterized, basically, by the use of spaced vertical elements. The vertical elements may be used as a rotating pair or in a fixed four-element system feeding a goniometer at the centre. The latter method begins to exhibit octantal error at frequencies where element spacing exceeds about one-tenth of a wavelength. In the fixed element system, particularly, both grounded monopole and elevated dipole systems have been used successfully. The Adcock is generally more sensitive than spaced-loop systems of reasonable size.

Although the Adcock system is theoretically immune to polarization error where perfect balance is maintained and pickup on the horizontal lines is eliminated, such an ideal condition is never achieved in actual practice. An important disadvantage is an inherent limitation in vertical elements—pickup of the wanted vertical component of the received wave falls off rapidly as the vertical angle of arrival increases. At angles greater than about 45°, the Adcock not only has reduced pickup but is inferior to the spaced-loop system in accuracy, since the wanted pickup is greatly reduced and the unwanted pickup remains constant. As with any null method, the introduction of small unwanted signals is damaging. However, although there is reduced pickup by vertical elements at high angles of wave arrival, over the longer distance paths, the stronger component will usually be one arriving at low angles. Consequently, the Adcock is quite generally regarded as superior to spaced loops, where bearings are taken over distances greater than about 650 km (400 miles).

1.3 *Doppler system*

The Doppler method of direction finding utilizes a rotating antenna rotated either physically or electrically, which causes the received emission to be raised in frequency as the antenna moves toward the source and to be lowered in frequency as it moves away from the source. At two points, half-way between, the instantaneous frequency of the received signal is unchanged.

In actual practice the system usually consists of a large number of vertical antennae, each connected through a transmission line to one terminal of a rotating capacity switch. The receiver is connected to the switch rotor and is thus connected to successive antennae. The received frequency is phase-modulated at the rate of rotation of the rotor, and is usually multiplied in the receiver to produce frequency-modulation. After heterodying the signal to a suitable intermediate frequency and feeding it into a discriminator, an audio-frequency is produced, the phase of which can be compared with a reference signal derived from the rotation of the rotor.

The radius of the antenna circle is limited to one-half wavelength at the highest frequency of operation to avoid ambiguities. This system is relatively immune to moderate fading or other amplitude variations since limiters effectively remove amplitude variations. It can be expected that there would be some complications, if not severe difficulties, in using this system on those types of waves where all of the components vary continually in frequency, such as single-sideband voice emissions or frequency-modulated emissions. A serious practical disadvantage in the Doppler system is an extremely critical requirement for precisely equal electrical lengths of transmission lines. This method of direction finding has, up to the present, found limited use.

1.4 *Wullenweber system*

The Wullenweber method of direction finding utilizes a large number of vertical antennae symmetrically mounted in a circle equidistant from a circular screen. Each antenna is connected through a transmission line to a capacity stator segment of a rotating switch. Several rotor segments are used simultaneously and are connected to the receiver through individual delay lines which cause the signals from the coupled antennae to arrive at the receiver in phase, thus producing the sharp beam of a broadside array. Maximum gain is on the axis of symmetry, but the side-lobe level is down only about 12 dB. However, the pattern can be sharpened by introduction of loss into the off-centre antenna circuits.

Since this is a wide-aperture antenna wherein a relatively large portion of the wave front is received, distortion of irregularities in the wave front do not result in the degree of error that appears in narrow-aperture systems. Also, since several antennae are feeding the receiver simultaneously, a slight irregularity introduced by or from any one antenna is not nearly so serious as where each antenna is swept singly and in succession. Hence, transmission-line lengths are not considered quite so critical as in the Doppler system.

1.5 *Doc. VIII/87 (India), 1963–1966*

1.5.1 Direction-finding equipment with 8 element Adcock antennae, rotating goniometer and automatic visual indicator is being used at the monitoring stations of the Indian Administration. By the use of a suitable pre-amplifier after the goniometer at the centre of the antenna system and using simple remote control technique, it is possible to locate the antenna system at a distance of 300 m from the main reception/indicator equipment.

1.5.2 For the type of direction-finding equipment indicated, it is possible to have the remote control facility at a moderate extra cost. The availability of the direction-finding equipment alongside other monitoring equipment has proved to be most convenient in the monitoring work. The same operator who is working on a monitoring channel can quickly take bearings of any station he desires. Selection of site with respect to the main monitoring building does not become very critical, as the antennae can be located up to a distance of 300 m from the main building. The effect of other antennae in the field also can be thus reduced.

1.5.3 The commercial direction-finding equipment has been modified to use a monitoring receiver which has better frequency stability (calibration at every 1 kHz interval right up to the highest frequency of 30 MHz). This again provides a great facility in tuning quickly and correctly the wanted station for the direction-finding bearing.

1.5.4 The above direction-finding system provides the bearing accuracy between $\pm 1°$ for stable signals exceeding 50 µV/m and $\pm 2°$ for stable signals exceeding 3 µV/m. Considering that, in the HF spectrum, the bearing inaccuracies contributed by fading and instability of the signals and other factors could be of this order, it is felt that the basic accuracy of the equipment as mentioned above should be adequate for monitoring purposes.

1.5.5 The direction-finding system employing a rotating goniometer has certain disadvantages as compared with one using phase/amplitude balanced amplifiers etc. With the rotating goniometer type, bearings are difficult to take in the presence of interference. Separate calibrations are required when selectivity of the receiver is changed and it is not always possible to choose the optimum selectivity to avoid interference. Most systems can, therefore, offer either one or two selectivities such as 1·2 kHz or 3 kHz. Proper adjustments of tuning, gain control, settings, etc., are required for taking good bearings. However, usually trained operators are employed at monitoring stations, hence these drawbacks can be overcome to some extent. This type of direction-finding equipment is fairly cheap.

1.5.6 It is the experience of the Indian Administration that operational personnel for taking bearings in the HF bands require considerable training. This involves training in proper adjustments of various controls as also training in taking bearings specially when the signals are fading or the bearings are swinging. Untrained operators tend to read bearings with certain bias towards one particular value, thus tending to give a false indication of class of bearings.

2. Mobile direction-finder

Because of the requirements of portability, mobile-unit direction-finders normally used in automobiles are necessarily limited to types that are small physically and easily manipulated. For the HF range, the most practical choice is a rotating loop. Since mobile units operate primarily within a pre-determined fix area and generally within the ground wave of the unknown target transmitter, quite satisfactory results have been obtained with a simple rotating loop. In general, the requirement of a boom for either spaced loops or spaced vertical elements practically eliminates these types from consideration for mobile units.

2.1 The accuracy of single-loop direction finders depends greatly on the polarization and angle of arrival of the wave-front. On ground-wave signals, where there is no sky-wave component present, and where there is little or no local distortion of the wave-front, due to local reflection or re-radiation of the signal, accuracies approaching $\pm 2°$ are possible. Under field conditions usually encountered, an accuracy of about $\pm 5°$ may be expected. However, in areas where local conditions distort the wave-front or where a significant sky-wave component is present the expected error may increase to several times this value.

The accuracy of mobile-unit loop bearings on ground-wave emissions can be improved by averaging multiple bearings, as with long-range direction finders. The advantage of a calibration curve, covering the full 360° of azimuth, when the direction finder is mounted on an automobile, should not be overlooked. Check bearings should be taken on known transmitters to confirm the proper operation of the equipment.

3. Accuracy of bearings and positions

3.1 *Classification of bearings*

Appendix 23 of the Radio Regulations stipulates that, to estimate the accuracy and determine the corresponding class of a bearing, the operator should use the observational characteristics shown in Table I. It adds that the operator may, when time permits, take into account the probability of error in the bearing.

A bearing is considered to belong to a particular class if there is a probability of less than one in twenty that the bearing error exceeds the numerical values specified for that class in Table I.

The Appendix adds that this probability should be determined from an analysis of the five components that make up the total variance of the bearing (instrumental, site, propagation, random-sampling and observational components).

This description gives no more than very general guidance without going at all deeply into the subject.

The following represents an attempt, to group together the existing data in technical literature on the operation of direction-finding systems.

The bearings are classified for accuracy, into the four classes defined in Table I, i.e.:

TABLE I

Classification of bearings

Class	Bearing error (degrees)	Observational characteristics					
		Signal strength	Bearing indication	Fading	Interference	Bearing swing (degrees)	Duration of observation
A	±2	very good or good	definite (sharp null)	negligible	negligible	less than 3	adequate
B	±5	fairly good	blurred	slight	slight	more than 3 less than 5'	short
C	±10	weak	severely blurred	severe	strong	more than 5 less than 10	very short
D	more than ±10	scarcely perceptible	ill-defined	very severe	very strong	more than 10	inadequate

Class A : probability of less than 5 % that the error exceeds 2°.
Class B : probability of less than 5 % that the error exceeds 5°.
Class C : probability of less than 5 % that the error exceeds 10°.
Class D : bearing with an error greater than those in Class C.

Taking Table I as the reference, a bearing will be a Class A (i.e., a good) bearing when, during the assessment, all the conditions enumerated in line A of the Table are fulfilled.

A bearing will belong to Class B, that is, it may be regarded as satisfactory, when at least one of the conditions in line B of the Table is fulfilled.

Similarly, a bearing will fall into Class C and be regarded as fair only, when at least one of the conditions specified in Line C of the Table is present.

A Class D bearing will merely give an idea of the sector in which the transmitter is located.

3.2 *Errors in bearings*

Bearings obtained with a direction-finder are subject to errors due to:

- equipment
- site of the direction-finder
- propagation
- operator.

Errors due to the equipment result from its design, as in the case of the octantal error for example. These errors are taken into account by the calibration arrangement of the apparatus.

Errors due to the site arise from irregularities in the configuration or composition of the terrain in the vicinity of the direction-finder. These errors vary with direction and frequency. They may thus be regarded as variable errors.

The third type of error is due to irregularities in propagation. These may give rise to side deviations in the propagation direction relative to the direction of the arc of the great circle between the transmitter and the direction-finder.

Moreover, irregularities in propagation give rise to errors due to polarization, which changes from one moment to the other in the case of ionospheric propagation.

Changes of direction due to irregularities in propagation may be either slow or rapid. Consequently, it is not possible to be sure of the real value of a bearing of a transmitter when observations are confined to a period of a few minutes, because the effect of slow changes in the propagation direction is then overlooked. To take this variable factor into account, it is generally necessary to extend the observations over several hours.

This means that, to improve accuracy, there is no point in making more than ten consecutive measurements, but these measurements should be repeated at intervals of one hour or more.

Operator errors, with the exception of those made accidentally, arise from a tendency, when making a series of measurements on the same transmitter, to take figures close to one another. This tendency is more marked with manually operated radiogoniometers than with automatic ones.

The conclusion may be drawn, therefore, that, when determining an azimuth, in addition to the systematic error of the equipment, which will be allowed for during calibration, other errors exist.

This raises the following questions among others:

- how should the measurements be carried out,
- what value should be taken for the bearing,
- how should the bearing be classified.

Since the measured values of a given transmitter change from one moment to another, it may be assumed that their distribution follows the Gaussian law.

The series of measurements obtained may, therefore, be defined by the following two values:

- the median value of the series, namely that taken from the series for which there are as many greater as smaller values. In other words, the value exceeded in 50% of the cases;
- the variance, measuring the scatter of the series. If v_1 is the variance, its value will be:

$$v_1 = \frac{(a_1-a_m)^2 + (a_2-a_m)^2 + \ldots\ldots (a_n-a_m)^2}{n-1} \qquad (1)$$

$a_1, a_2, \ldots\ldots a_n$, are the values measured, a_m the arithmetic mean of these values and n the number of values in the series.

3.2.1 *Measurement procedure*

If the figure shown by the direction-finder remains unchanged (as in the case of ground-wave transmission), only this figure need be taken.

However, if the figure shown changes from one moment to another, 10 to 15 readings should be taken over a period of something like 5 minutes. The readings should be made at regular intervals and the tendency to take figures close to one another should be avoided.

With these figures, one can see from Table I to which class the bearing belongs.

3.2.2 *Figure to be taken*

The figure to be taken for the bearing is the most probable value in the series, namely, the arithmetic mean of the values obtained.

3.2.3 *Classification of bearings*

The method of classifying the bearing indicated above is somewhat subjective. Let us consider a more objective way.

To classify a bearing, the total variance of the arithmetical mean of the results must be known, since these are influenced, as shown above, by several sources of error.

Allowance must also be made for another source of error, namely the limited number of measurements.

If, instead of making only 10 to 15 measurements during 5 minutes, a greater number of measurements was taken over a longer period, a different mean value would be obtained, which would be closer to the actual value.

This means that, when several groups of measurements are taken on the same transmitter, each group will have a mean value different from the others. The complete set of these mean values will constitute a series, likewise distributed in accordance with Gussian law, and with a variance of v_a.

It is known that in this case,

$$v_a = v_1/(n-1) \text{ is obtained.} \tag{2}$$

The calculation of v_a is a very lengthy operation,

$$v_a = r^2/(n-1)d \text{ may be taken,} \tag{3}$$

where r is the difference between the maximum and the minimum values of a series of 10 to 15 measurements and d the value deduced from the curve in Fig. 1.

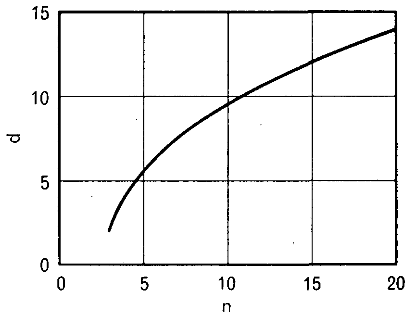


FIGURE 1

$d = r^2/v_1$

The expression can thus be easily applied.

With

$$3 \leqq n \leqq 12$$

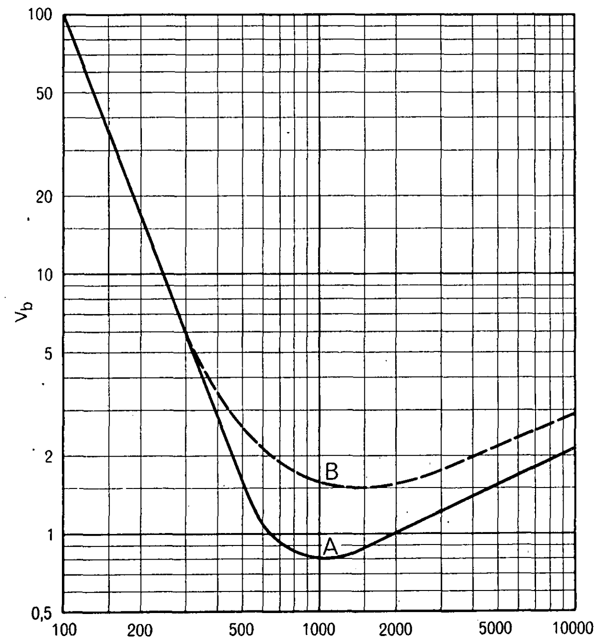
one need merely take

$$v_a = r^2/n^2 \tag{4}$$

Let us now examine errors due to a long-term change in the propagation direction.

Without any correction of the bearings on the same transmitter, taken with the aid of two conveniently sited direction finders, a very good idea is obtained of the distance at which the transmitter is situated. With this distance value and provided that the measurements have been made over a period of 5 minutes, the experimental curve in Fig. 2 gives the value v_b of the variance due to this source of error.

As regards errors due to the siting of the direction finder, no expression can be given for determining the value v_c of the corresponding variance.



Distance (km)

FIGURE 2

A: day
B: night

The only way to ascertain v_c is through the study of the average errors obtained over periods of several months on known transmitters with stable propagation.

As a general rule, values of v_c are taken for different frequency bands. For example, a rounded-off value for the 3-5 MHz band ,another for the 5-10 MHz band, yet another for the 10-15 MHz band, and so forth.

The operator error resulting from the tendency to narrow down the spread of the measured values, corresponds to a variance v_d which may be ignored with an automatic direction-finder, provided the operator is duly forewarned and which, with a manual one used in the same circumstances, may be taken as:

- equal to zero, if the total width of the minimum is less than 10°, which represents a 5° uncertainty on either side of the middle point of the sector;
- equal to 1, if the total width of the minimum is comprised between 10° and 20°;
- equal to 4, if the total width is comprised between 20° and 40°;
- equal to 25 if the total width is over 40°.

The total variance will be

$$v = v_a + v_b + v_c + v_d \qquad (5)$$

With a known v, Fig. 3 gives the error in the bearing with a probability of 95 %. This is the error shown in Table I. Thus it may be said that:

- a bearing will fall into Class A, if the total variance is less than 1;
- into Class B, if the variance is comprised between 1 and 6·5;
- into Class C, if the variance is between 6·5 and 25;
- into Class D, if the variance is over 25.

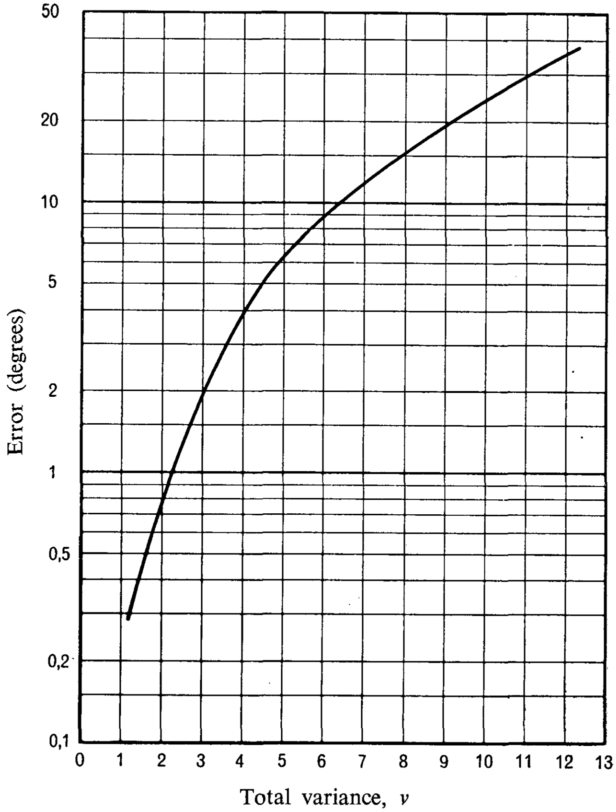


FIGURE 3

3.3 *Classification of positions*

The Radio Regulations give the following classification of positions:

- Class A: positions which the operator may reasonably expect to be accurate to within 5 nautical miles;
- Class B: to within 20 nautical miles;
- Class C: to within 50 nautical miles;
- Class D: positions which the operator may not expect to be accurate to within 50 nautical miles.

3.4 *Determination of position*

Let us consider how a position can be determined, using two direction finders. The cross-bearing of the two bearings obtained gives a point, but because of errors, one cannot be sure that this point is the site of the transmitter.

Similarly, using three direction finders, a triangle is obtained with the three bearings (see Fig. 4, triangle *DFH*). In this case too, one cannot be sure that the transmitter is located within this triangle.

Let us suppose that the median error of two of these direction finders (for example, *A* and *B*) is nil; that is, that there is an equal probability that the two azimuths obtained are located to the right or to the left of the transmitter.

On whatever side the bearing obtained with the third direction finder *C* is located (for instance, side CC_1, Fig. 5), there are four possibilities (shown in the following Table II).

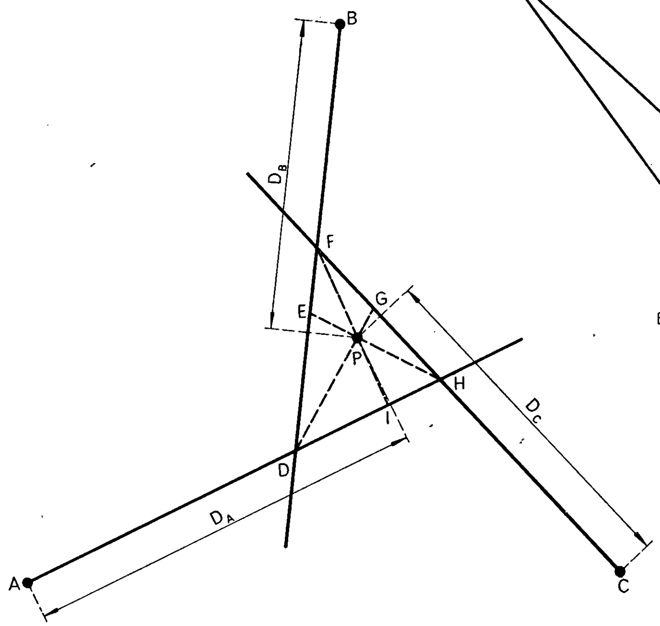


FIGURE 4

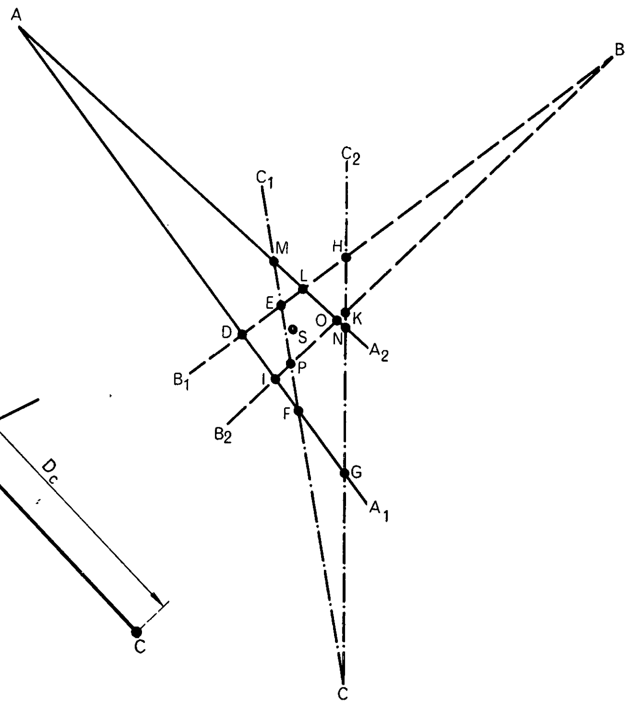


FIGURE 5

TABLE II

Azimuths	Triangle	Site of the transmitter
CC 1 *AA* 1 *BB* 1	*DEF*	outside the triangle
CC 1 *AA* 2 *BB* 2	*ELM*	outside the triangle
CC 1 *AA* 1 *BB* 2	*IFP*	outside the triangle
CC 1 *AA* 2 *BB* 2	*MOP*	within the triangle

Consequently, where the median values of the errors of two of the direction finders are both nil, the probability that the transmitter is situated outside the triangle is 75%.

It may be concluded that, if the triangle is small (with the median value of the error approaching zero), the transmitter is probably outside this triangle.

The practical problem to be solved is as follows: how to determine the probable location of the transmitter, with given bearings and their attendant errors.

The problem should be solved in two stages:

- plot on the map the most likely point corresponding to the bearings obtained;
- plot the contour, with this point as a centre, corresponding to a given probability that the transmitter is sited within it.

3.4.1 *The most likely point*

With two bearings, the most likely point for plotting on the map is their intersection.

With three direction finders (the most current practice), the azimuths obtained will be, for example, those shown in Fig. 4, where *A*, *B* and *C* are the sites of the direction finders.

Let us designate by D_A, D_B and D_C the distances from the goniometers to the most likely point. Since the location of this point is not yet known, these three distances can only be given somewhat approximately, it being understood that the siting is provisional.

Let us designate by v_A, v_B and v_C the variances for the three direction finders, calculated as shown in § 3.2.3.

The most likely point, *P*, is the point of intersection of the straight lines drawn from the apices of the triangle to points *E*, *G* and *I* these points being determined from the following equations:

$$GH/FG = (v_C/v_A)\,(D_C \sin HFD)^2/(D_A \sin FHD)^2 \quad (6)$$

$$EF/DE = (v_B/v_C)\,(D_B \sin FDH)^2/(D_C \sin HFD)^2 \quad (7)$$

$$DI/HI = (v_A/v_B)\,(D_A \sin FHD)^2/(D_B \sin FDH)^2 \quad (8)$$

The position of point *P* will thus be a function of the distances from the transmitter to the direction finders and of the errors of each instrument. The smaller the error of one direction finder, the closer point *P* will be to the bearing obtained with that instrument.

Taking, for example, a network of three direction finders, forming an equilateral triangle, and the errors for the three being equal, Fig. 6 will give the position of the most likely point for different cases.

3.4.2 *Determination of the contour*

The contour corresponding to a given probability that the transmitter is located within it, is an ellipse with the most likely point as its centre.

Let the reference be a set of rectangular axes, with the most likely point as the origin; the axis will be oriented in accordance with the meridian of this point.

With *p* as the probability, the ellipse will be defined by

$$\frac{x^2}{b^2} + \frac{y^2}{a^2} = -2\log_e(1-p) \quad (9)$$

in a set of axes having the most likely point as their origin, but shifted in relation to the preceding set, by an angle φ, measured from the North, and given by

$$\tan 2\varphi = 2\,s/(t-u) \quad (10$$

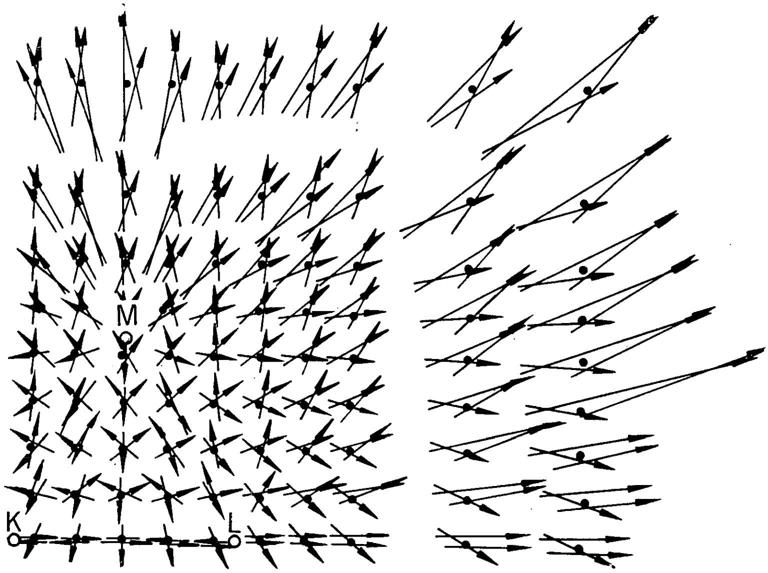


FIGURE 6

this gives

$$s = \sum_{j=1}^{n} (\sin \theta_j \cos\theta_j)/D_j^2 \, v_j \qquad (11)$$

$$t = \sum_{j=1}^{n} \sin^2 \theta_j/D_j^2 \, v_j \qquad (12)$$

$$u = \sum_{j=1}^{n} \cos^2 \theta_j/D^2_j \, v_j \qquad (13)$$

θ_j is the bearing obtained with direction-finder j ($j = 1, 2, \ldots$),
D_j the distance from the most likely point to direction-finder j,
v_j the variance corresponding to direction-finder j;

a and b are given by

$$t - s \tan\varphi = 1/a^2 \qquad (14)$$

$$u + s \tan\varphi = 1/b^2 \qquad (15)$$

The values a_1 and b_1 of the semi-axes of the ellipse corresponding to a probability p will be (see equation (9)):

$$a_1^2 = -2a^2 \log_e(1-p) = -\frac{2 \log_e(1-p)}{t - s \tan\varphi} \qquad (16)$$

$$b_1^2 = -2b^2 \log_e(1-p) = -\frac{2 \log_e(1-p)}{u + s \tan\varphi} \qquad (17)$$

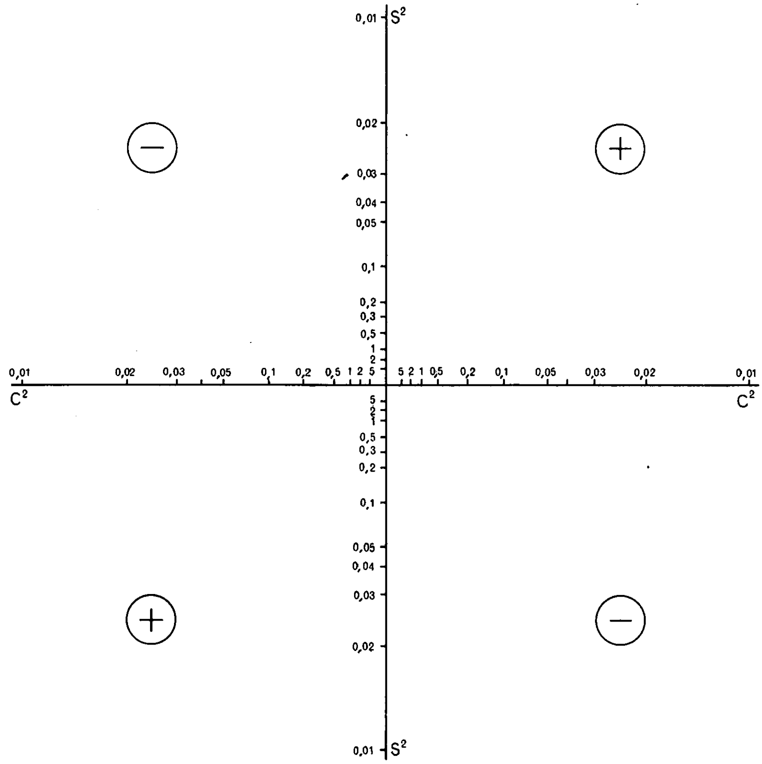


FIGURE 7

As, in general, the ellipse corresponding to $p = 0{\cdot}5$ is adopted,

$$a_1^2 = 1{\cdot}39/(t - s \tan\varphi) \tag{18}$$

and

$$b_1^2 = 1{\cdot}39/(u + s \tan\varphi) \tag{19}$$

will be obtained.

3.4.2.1 *Determination of the ellipse, by the Hopkins method*

The earlier method, devised by Stansfield, is a fairly lengthy operation.

Let us take a set of axes (Fig. 7) plotted on tracing paper, approximately 25 cm long.

The scales of these axes give the inverse square of the distance to the origin, measured in centimetres.

The arithmetical signs shown in the figures are allocated to each sector defined by the axes.

The tracing paper is superimposed on the map, making the origin of the axes coincide with the most likely point and with the axis s^2 oriented according to the meridian of this point.

The straight line which, on the map, links the site of the direction finder to the most likely point, is then turned clockwise at an angle equal to the square root of the variance corresponding to the direction finder.

The straight line thus turned intersects the axes s^2 and c^2 and the corresponding points can be read thereon. These values (l_1 and m_1) are then entered

TABLE III

Direction finder	Scale readings		Sign	Values of s_c
	s^2	c^2		
1	l_1	m_1		$\sqrt{l_1 m_1}$
2	l_2	m_2		$\sqrt{l_2 m_2}$
3	l_3	m_3		$\sqrt{l_3 m_3}$
.	.	.		.
.	.	.		.
.	.	.		.
Total	L	M		Algebraical sum = N

in the second and third columns of Table III. The sign of the sector within the two semi-axes thus intersected is entered in the fourth column.

The same procedure is used for the other direction finders and the corresponding values (l_2 and m_2, l_3 and m_3 . . .), together with the arithmetical signs, are entered in Table III

The values for $\sqrt{l_1, m_1}$, $\sqrt{l_2, m_2}$ . . . . are calculated and entered in the fifth colum of the Table.

The sum is then calculated of the values of the second and third columns and the algebraical sum of the fifth column (using the signs in the fourth column).

The angle of rotation φ of the axes of the ellipse, in relation to the axes having the most likely point as their origin and constituted by the meridian and a straight line perpendicular thereto, is given by

$$\tan 2\varphi = 2N/(L - M) \tag{20}$$

The values a_1 and b_1 of the semi-axes of the ellipse, oriented respectively, in accordance with the y–axis (northward axis through φ^o) and the x–axis are

$$a_1^2 = -2 \log_e (1 - p)/(L + N \tan \varphi) \tag{21}$$

$$b_1^2 = -2 \log_e (1 - p)/(M - N \tan \varphi) \tag{22}$$

Where $p = 0{\cdot}5$,

$$a_1^2 = 1{\cdot}39/(L + N \tan \varphi) \tag{23}$$

and

$$b_1^2 = 1{\cdot}39/(M - N \tan \varphi) \tag{24}$$

will be obtained.

The values of a_1 and b_1 will be given in centimetres.

3.4.3 *Classification of position*

The procedure described in § 3 is used; in addition, the value of the semi-major axis of the ellipse may be taken.

Nevertheless, it is better to take the value

$$\rho = \sqrt{a_1^2 + b_1^2} \tag{25}$$

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ANNEX

Comments concerning HF long range direction finder used at monitoring stations in the U.S.A.

1. Description

An Adcock direction finder in use in the U.S.A., having a useful frequency range of 2 to 40 MHz, utilizes two vertical dipoles each about 6 m (20 feet) long and spaced about 6 m (20 feet) apart. The centre line of the dipoles is approximately 6 m (20 feet) above the ground. Provision is made for manually or automatically controlled rotation with a maximum rotational speed in the latter condition of 20 to 30 revolutions per minute. Provision is made for aural or visual readout of the bearing; also for automatic averaging of the bearings over a period of up to 20 or more rotations of the array with a visual display of the averaged bearing.

2. Bearing accuracy

In a series of tests over a period of several months in 1962, Adcock bearings were taken on 60 W transmitters in locations unknown to the observers. The distances involved were random to simulate the conditions of actual problems and varied from a few hundred to more than 1600 km (1000 miles) in the various tests. Thirteen Adcocks in widely separated locations produced bearings having an accuracy of 2° or better in 82% of the tests. For further information on this subject of bearing accuracy, see Report 93.

REPORT 373 *

ANTENNAE FOR MONITORING STATIONS

(Question 11/VIII)

(1966)

This Report takes account of the documents presented during the period 1963–1966 and of Report 278–1.

1. Doc. VIII/6 (U.S.A.), 1963-1966

1.1 In considering the extent to which currently available antennae fulfil the requirements of monitoring stations, it must be realised that requirements may differ according to the type of monitoring functions being performed. For general surveillance of the spectrum for example, it is often desirable to use an antenna with essentially omnidirectional characteristics, whereas for detailed study or analysis of a particular emission, a directional array may be needed to attenuate unwanted emissions. Therefore, the comments contained herein will take into account the need for both omnidirectional and directional antennae. The wide frequency range which monitoring stations are required to cover, precludes any single type of antenna from giving satisfactory results over the entire range. Therefore, the following discussion will devote itself to separate comments on bands 4 to 10.

1.1.1 *VLF antennae*

Because of the tremendous wavelengths involved in band 4, it is generally impractical at monitoring stations to use an antenna having a physical length exceeding more than a very small percentage of a quarter wavelength. Commonly used antennae in this range include simple verticals, top-loaded or umbrella-loaded verticals, flat-tops and loops. A relatively recent innovation is a loop designed for reception of VLF standard-frequency transmissions, which makes use of ferrite materials to increase the signal pickup and to provide directivity. Complete antenna systems, consisting of either a vertical antenna or a large fixed loop with an integral matching network, bandpass filter and solid-state pre-amplifier, are also being used to increase the signal-to-noise ratio and signal input level to the receiver. Ability to change polarization of the receiving antenna is not important in the VLF range, since in most instances the polarization of the incoming signal is predominantly vertical.

1.1.2 *LF antennae*

The situation in band 5 is in some ways similar to that in band 4, except that, as the frequency is increased, useful antennae can be made somewhat smaller. Beverage antennae are useful where adequate space is available and where advantage can be taken of the relatively good horizontal directivity obtainable from such antennae.

1.1.3 *MF antennae*

In many areas of the earth, high directivity of a receiving antenna is, at least, equally as important as affective length, in view of the congested nature of band 6 especially in the MF broadcast band. Beverage antennae for this range are quite

* This Report was adopted unanimously.

useful, as are loops, either air wound or on ferrite cores. However, more sharply directional antennae of moderate size would permit more effective monitoring of the MF range than can presently be accomplished except with expensive or space-consuming arrays.

1.1.4 *HF antennae*

Most monitoring stations participating in the international monitoring system will probably need both non-directional and directional antennae for use in the HF range (band 7), the former for general spectrum surveillance and the latter for observation or study of specific signals or azimuth segments. Broadband antennae, with essentially equal signal response at all azimuths, are available from several sources. These are typically vertical arrays consisting of several elements in parallel to obtain broadband response. Another method of obtaining broadband frequency response from a vertical antenna is described in Report 278-1.

Although widespread use has been made of rhombic antennae for monitoring in band 7, their large dimensions, together with rather erratic frequency/directivity-gain characteristics and a tendency toward unwanted side and back reception lobes, make them less than ideal in this application. Development during the past few years of log-periodic and other wideband directive antenna systems represents a major advance in antennae with characteristics which suit them for monitoring use. However, log-periodic antennae likewise have shortcomings. They have generally lower gain than a rhombic antenna covering the same frequency range, although the response is generally more constant over its design range. Likewise, although land-space requirements are generally moderate, the construction costs tend to be greater than for a comparable rhombic array. One desirable characteristic of the log-periodic array is the relative absence of reception lobes from the sides and back, along with good front-to-back reception ratio, an important feature for monitoring in the crowded band 7.

For coverage of limited frequency ranges, there are numerous types of antenna arrays which satisfy most directivity and gain requirements. However, few monitoring systems are likely to find that their antenna needs are met by such narrow-band coverage. Although it may at times be desirable to be able to change the polarization of the receiving antenna to conform to that of the transmitting antenna, it has been found that, in general, especially over long sky-wave paths, the wave front polarization is considerably distorted so that both horizontal and vertical components will be present in the received signal regardless of the initial polarization. However, further study in this connection might well be undertaken.

1.1.5 *VHF antennae*

Extensive experimentation in band 8 has resulted in the development of many types of antennae having desirable characteristics for monitoring use. Broadband log-periodic antennae are available, which respond to various wave polarizations, either simultaneously or by means of simple switching techniques; both broadband and narrowband Yagi-type arrays are available in abundance to meet almost any conceivable monitoring need. Other useful antennae for the upper VHF range include corner-reflector arrays and broadside arrays of dipoles with plane reflectors.

1.1.6 *UHF-SHF antennae*

As in band 8, monitoring observers desiring to operate in bands 9 and 10 may select from many excellent types of antenna, ranging from scaled-down versions of VHF antennae in the lower portion of band 9, to elements mounted in parabolic reflectors starting around 1 GHz. It is fortunately true that, although the effective length of a simple resonant antenna becomes shorter with increasing frequency, the use of signal concentrators, such as parabolic reflectors, permits a higher effective gain than is reasonably possible at lower frequencies. Recent developments in log-periodic and horn antennae designed for mounting in parabolic reflectors, have provided needed improvements in achieving broadband directive response in the microwave regions. At least one manufacturer offers a log-periodic and parabolic reflector combination providing coverage from 1 to 10 GHz with quite respectable gain. Where greater gain is required, a series of four horns may be used interchangeably with the log-periodic element, and additional horns are available to extend the range to 21 GHz. The reflector is small enough to permit ready mounting on the roof of an automobile where mobile observations are needed. A signal gain of 25 dB or more over a half wave dipole is possible with the horns at frequencies above about 5 GHz with somewhat less gain at the lower frequencies, primarily because of the small size of the parabolic reflector. For fixed operation, the log-periodic and horn units may be installed in large parabolic reflectors to obtain greater gain, for activities such as space monitoring (see Question 6/VIII and responses thereto).

1.2 *Desirable characteristics of antennae*

Although the characteristics desired of an antenna will depend upon the intended use, in most instances the fundamental requirement is to obtain the greatest possible signal input to the receiver from the wanted signal and at the same time to attenuate unwanted signals and noise to levels which do not cause interference. There are, of course, exceptions to this rule where general spectrum surveillance is being performed or where it is desired to observe relative signal levels of two or more emissions on the same or adjacent channels. Rejection of unwanted signals can be accomplished by providing horizontal or vertical directivity, or both. The use of antennae with very narrow bandwidth or having limited response at certain frequencies may also be desirable in some instances, especially where strong unwanted signals are present which might overload or desensitize the receiver. However, attenuation of such signals by means of resonant filters inserted between the antenna and the receiver is usually more effective than attempting to eliminate the signal within the antenna itself. At the higher frequencies, certainly in the VHF and higher ranges, considerable attenuation of unwanted signals can often be accomplished by using antennae which have optimum response to the mode of polarization of the wanted signal and which are relatively insensitive to other propagation modes. Where two or more modes of polarization are commonplace, it may be desirable to be able to alter the antenna polarization response, either by a simple switching arrangement or by actual rotation of the antenna about its major horizontal axis. For example, a single Yagi or log-periodic array can readily be designed for alternate reception of either vertical or horizontal polarization by either of these two methods. Where it is desired to receive both horizontally and vertically polarized signals simultaneously, two separate antennae may be used, or the elements of a single antenna may be so arranged as to permit pickup of both polarization modes. Reception of signals having other types of polarization (e.g. circular, elliptical, etc.) can usually be accomplished with general purpose antennae, although specially designed antennae may be more effective.

1.3 *Needed improvements in the characteristics of the monitoring antennae*

1.3.1 *In the VLF and LF ranges (bands 4 and 5)*, greater signal pickup from relatively small antennae would be desirable; equally important is the matter of improving the signal-to-atmospheric noise ratio, since atmospheric noise is often the limiting factor in weak signal reception at the lower frequencies. One area which might well be explored would be the improvement of the directional characteristics of VLF-LF antennae not only to eliminate unwanted signals but also to reduce the atmospheric noise input to the receiver, by minimizing noise pickup from all directions, except the path of arrival, of the wanted signal.

1.3.2 *In the MF and HF ranges (bands 6 and 7)*, more highly directional antennae of moderate size, preferably adjustable in azimuth, would be helpful. Although Beverage and rhombic antennae and other currently used directional arrays are reasonably satisfactory for reception over about 20° of horizontal arc, a considerable number of such antennae must be used to accomplish reception from all directions. Similarly, although broadband directional arrays such, as log-periodics, have been made rotatable, their dimensions are such that they must be solidly constructed to withstand wind and weather and the rotating mechanism adds considerably to their cost. Smaller antennae with comparable gain would undoubtedly be welcomed by monitoring station operators.

1.3.3 *In the VHF and higher ranges (bands 8, 9 and 10)*, the monitoring specialist probably has more to choose from in the way of desirable monitoring antennae than at the lower frequencies, largely because the dimensions are smaller and the physical problems of weight and size become less important. Even so, where very high gain is required (e.g. for monitoring weak signals from spacecraft), the large arrays presently being used become quite cumbersome. In such applications greater gain in more compact arrays would be desirable. The arrays should be readily adjustable both in azimuth and in elevation, should be capable of reception of emissions having a variety of polarization modes and should have a frequency response commensurate with the band or bands to be covered. To keep to a minimum the number of arrays required, when continuous coverage of bands 8, 9 and 10 (VHF, UHF and SHF ranges) is needed, each antenna array should preferably be capable of covering at least a frequency range of 2 to 1.

ANNEX

Examples of antenna systems suitable for stations participating in the international monitoring system

1. A basic antenna system with frequency coverage limited to the frequency range 500 kHz to 30 MHz

1.1 One or more broadband vertical antennae to provide coverage with a single array over a frequency range of 5 to 1 or more. Two or three such arrays will give complete coverage of the ranges of interest. For example, see Figs. 1 to 7 of the present Report.

1.2 Single-frequency or narrow-band monitoring and communication antennae as required to meet special needs.

2. A more elaborate antenna system for the range 500 kHz to 30 MHz

2.1 The antennae described in § 1, together with those described below.

2.2 To provide broadband directional-antenna facilities which are lacking in the basic system described above, either one or more rotatable log-periodic arrays or a series of rhombic antennae will permit greater flexibility of operation, especially on emissions having low signal levels at the monitoring site or where directional interference rejection is needed.

Coverage from about 6 to 30 MHz can be obtained with a log-periodic array of moderate size which can be installed to permit rotation for omni-azimuth use.

2.3 An Adcock direction finder may be used to advantage at a monitoring station for purposes other than the usual one of direction-finding. The directional characteristics are useful in nulling out unwanted signals while monitoring a co-channel station arriving from a different direction. Adcocks also have relatively good signal pickup for general monitoring at frequencies in the upper portion of their design range.

3. An antenna system providing wide spectrum coverage at a completely equipped monitoring station

3.1 All the antennae described in § 2 together with:

3.2 For use below 500 kHz, one or more rotatable loop antennae covering the frequencies of interest and one or more vertical or flat-top (multi-wire " T ") antennae.

3.3 For use in the VHF range, a rotatable log-periodic array, designed for reception of both horizontally and vertically polarized emissions, and other special purpose antennae to meet the particular needs of the station in this range.

3.4 For UHF-SHF use, special purpose high-gain antennae are usually preferable to broadband antennae with lower gain. For monitoring emissions from spacecraft, parabolic reflectors or other signal concentrators are recommended. For this purpose, it is important that the antenna array be moveable both in azimuth and elevation from the control position or that provision be made for automatic positioning control by the incoming signal.

Note. – At a completely equipped monitoring station, coupling between the multiplicity of antennae and between transmission lines may present a problem. This condition may be minimized by using multi-purpose antennae, including rotatable arrays, to reduce the number of antennae required and by making optimum use of coaxial cables in lieu of open-wire transmission lines. Installation of tuned pre-amplifiers at the antenna ends of the transmission lines will help to offset line losses where long lines must be used to achieve adequate spacing between antennae.

4. Document VIII/17 (United Kingdom), 1963-1966

4.1 *Antennae*

For monitoring up to 30 MHz, antenna requirements can be met largely by the provision of the following types:

4.1.1 *Wideband omnidirectional antennae for rapid exploration of the spectrum*

For the MF band, a vertical wire or mast and cage antennae are usually adequate. In the HF band, vertical cage antennae can provide omnidirectional facilities over a 2½ to 1 frequency range. Alternatively, an inverted cone antenna may be used to provide coverage over the range 12 kHz to 30 MHz (see § 8).

4.1.2 *Wideband directional antennae to aid identification and to provide maximum signal to noise and/or interference ratios*

In the HF band, a group of sloping wire antennae has the advantage of simple construction and reasonable directivity combined with all round coverage. Hence, twelve sloping wires, 150 m long, with a 1 in 5 slope, some 40 m high at the centre mast and 10 m high at the outer ends, would be satisfactory. Rhombic antennae also have the advantage of simple construction and reasonable directivity over a 4 to 1 frequency range. However, a number of such antennae is needed for complete coverage involving a considerable site area. Consideration may also be given to a rotatable log-periodic antenna, particularly for use above 10 MHz.

4.1.3 *Direction-finding installations to obtain bearings*

An Adcock system may be used to provide these facilities.

For monitoring between 30 and 300 MHz, it is generally desirable to provide rotatable directive wideband antennae installed at the top of a fairly high mast (45 m). By this means, it is possible to reduce the number of antennae required to cover the large frequency range involved and yet retain reasonable gain and directivity with sufficient resolution for coarse direction-finding purposes. Yagi and log-periodic antennae, both horizontal and vertical, are very suitable.

4.2 *Antenna feeders*

As far as possible, coaxial cables should be used for antenna feeders; where open-wire feeders are used it is necessary to pay careful attention to their balancing.

4.3 *Earth connections*

4.3.1 *Earth connections at monitoring station*

It is essential that a radio monitoring station should be provided with an adequate earth system. Such an arrangement might consist of four ungalvanized mild steel rods, about 2 m long and 20 mm in diameter, spaced some 2 m apart. One end of each rod could conveniently have a hardened tip and the other end could have a screw thread, to facilitate a good connection of the earthing lead. Alternatively, copper earth plates, for example 1 m square, might be used. In ground of poor conductivity, it may be necessary to increase the number of spikes or plates. Connections from the earth spikes or plates to the earth bar in the monitoring station may be made with cable with a conductor of large diameter.

4.3.2 *Earth connections at antennae*

Where earth connections are required for certain antennae, i.e. inverted-cone or sloping-wire antennae, these may be provided by laying, for example, 60 radials of copper wire, with a radius of 30 or 40 m.

5. Doc. VIII/26 (France), 1963-1966

5.1 *Land and antennae*

A monitoring centre must be installed on land which is as flat as possible and well away from any obstruction, metal obstacle or large clumps of vegetation. It should have an area large enough for the centre to be able to erect one or more non-directional antennae, covering the range of monitored frequencies and an array of directional antennae (rhombic), with the highest possible gain with which the direction of arrival of the waves received can be determined to a sufficient degree of accuracy.

5.2 *Non-directional antenna*

In practice, a single antenna may be used for the entire range of frequencies below 30 MHz.

It may consist of a vertical metal mast, about 8 m high, with a terminal capacity at the top and its base an earthing system of buried conductors in the shape of a star.

For greater safety and convenience, however, it is preferable to have several antennae of this type, especially if some of them are to be assigned to cover a specific frequency band.

5.3 *Directional antennae*

The possibility of using a radio direction-finder to determine the direction of wave arrival is not to be ruled out *a priori.*

However, apart from its high cost, this solution presents particularly difficult problems.

The method of comparing the level of signals received on different directional antennae is advocated. While this system cannot claim the accuracy obtainable with a direction finder, it is, on the other hand, much less costly and more quickly set up.

Finally, it is to be noted that high-gain directional antennae are also most valuable for identifying emissions received with low fields.

The number, type and direction of the antennae to be erected must be determined after studying the conditions peculiar to the monitoring centre in question.

6. Doc. VIII/23 (Italy), 1963-1966

In the Monza monitoring centre of Radiotelevision Italiana, an antenna system has recently been installed for the VHF and UHF frequency ranges, that has given satisfactory results.

This antenna system was installed on an iron tower 50 m high, the position of which, at a distance of 200 m from the centre, was chosen so as to avoid interfering with the existing antennae for the other frequency bands or affecting the field-strength measurements taken at the centre itself.

The antenna system consists of a rotatable supporting unit with variable speed, telecommanded from the centre. To this unit, which has a square section of two metres and a height of six metres, the following antennae are fixed:

6.1 for broadcasting band IV, two antennae, one for the reception of vertical-polarization emissions and one for horizontal-polarization emissions; each of them consists of four arrays of eight dipoles; each antenna has a gain of 17 dB in the 470–790 MHz range;

6.2 for broadcasting band III, two antennae, one for the reception of vertical-polarization emissions and one for horizontal-polarization emissions; the first consists of an 8-dipole array and the second of two adjacent 4-dipole arrays; each antenna has a gain of 12 dB in the 174–223 MHz range;

6.3 for broadcasting band II, one antenna for horizontal-polarization only, consisting of six Yagi three-unit antennae, arranged on two levels, with three antennae at each level; the gain of the system is 14 dB in the 87–108 MHz range;

6.4 for broadcasting band I, two antennae, one for the reception of vertical-polarization emissions and one for horizontal-polarization; each of them consists of two Yagi three-unit antennae, each antenna having a gain of 9 dB in the 52–68 MHz band.

All the antennae are connected to switching units located on the tower and remotely controlled from the centre, which enables a single transmission cable to be used for the various antennae.

The transmission cables between the antennae and the coaxial switching units are of the flexible type; the 260 m long cable between the antenna switching unit and the measuring apparatus is a 50 Ω cable of a diameter of 80 mm (3 1/8″), having an attenuation of 3·8 dB at 800 MHz.

It has not proved necessary to use antenna amplifiers.

7. Doc. VIII/2 (Japan), Washington, 1962

Figs. 1, 2 and 3 describe a vertical omnidirectional loaded antenna that has been used in Japan for the measurement of the relative field-strength (see also Report 278-1, § 4).

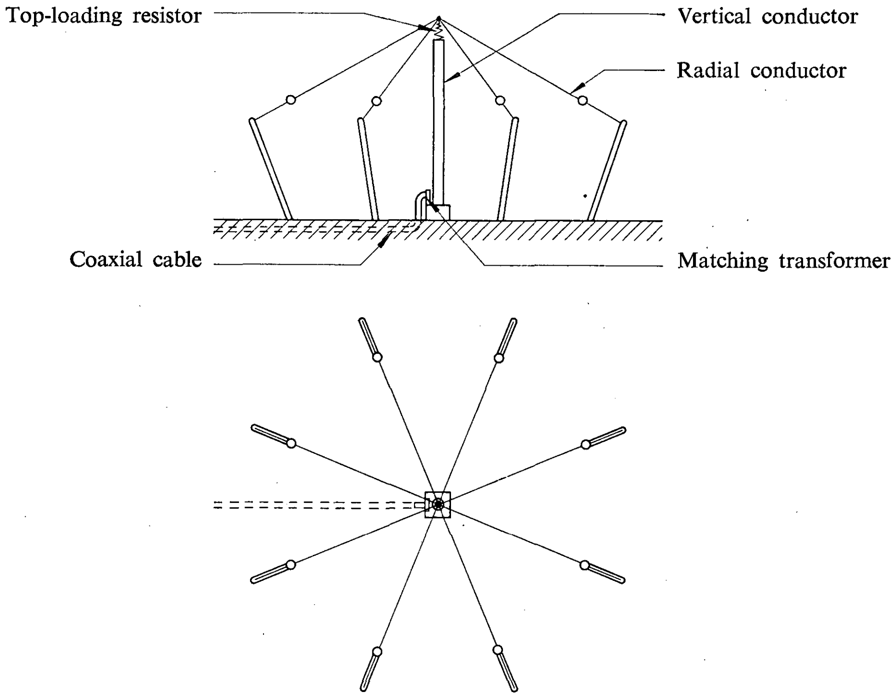

FIGURE 1

Vertical omnidirectional loaded antenna

Loading resistor : 250 ohms
Length of radial conductor: 8 m
Length of vertical conductor: 8 m

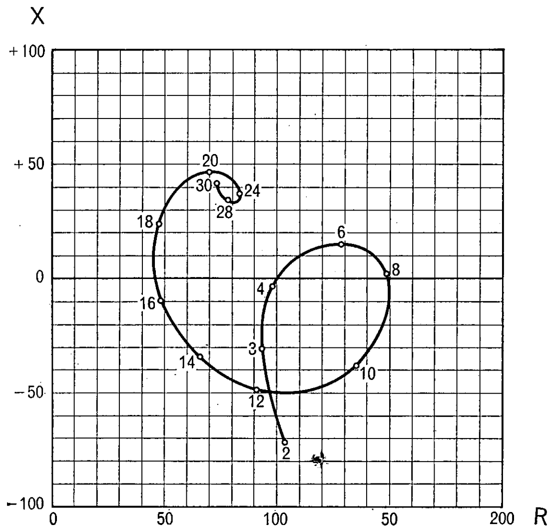

FIGURE 2

Impedance characteristics of a vertical omnidirectional loaded antenna
(see Fig. 1)

SWR: 2·0 (except at 2 MHz)
(The points on the curve represent the frequency in MHz)

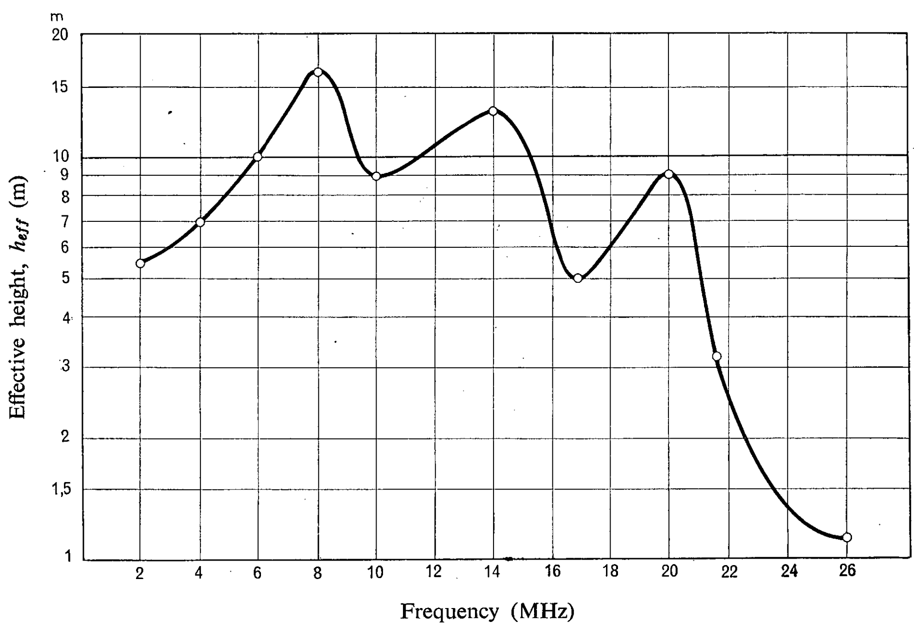

FIGURE 3

Effective height of a vertical omnidirectional loaded antenna
(see Fig. 1)

8. Doc. VIII/15 (United Kingdom), 1963-1966

Cone antenna

The inverted cone antenna is shown in Figs. 4 to 7. It consists of 16 equally spaced wires, 7·6 m high, terminating in a soldered connection at the apex. An associated buried radial earth consisting of 16 wires, each 10 m long, is necessary. A coaxial cable feeds the antenna to the receiving room, the centre conductor being connected to the apex and the outer conductor to the radial earth system. A property of such an inverted cone antenna is that the impedance, nominally 75 Ω, shows little variation over the frequency band and direct connection to a coaxial cable having a characteristic impedance of 75 Ω can be effected without serious mis-match.

The calibration curves shown in Fig. 8 have been derived from an installation similar to the one described. Curve *B* represents the correction factor without cable loss. Curve *A* has been calculated assuming a 400 m length of 75 Ω coaxial cable between antenna and receiver. A further calibration curve would need to be derived from curve *B* if a significantly different length or type of cable is employed. Measurements on 48 similar cone antennae in different locations, showed variations in the correction factor of less than ± 2 dB in 90% of the measurements.

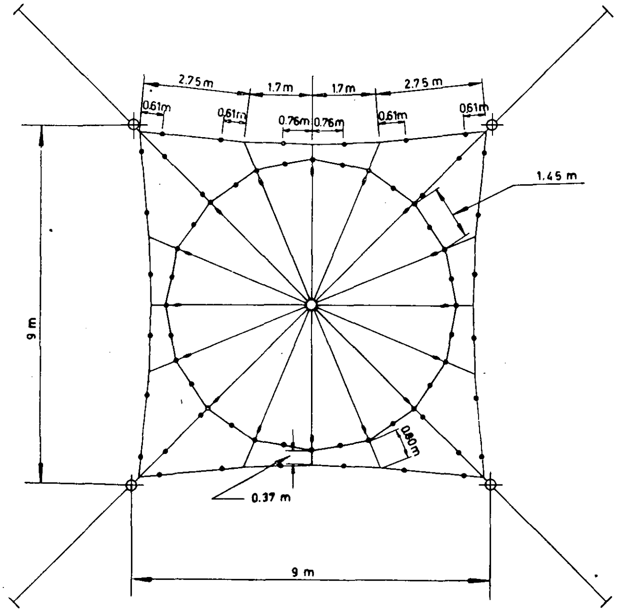

FIGURE 4

Plan

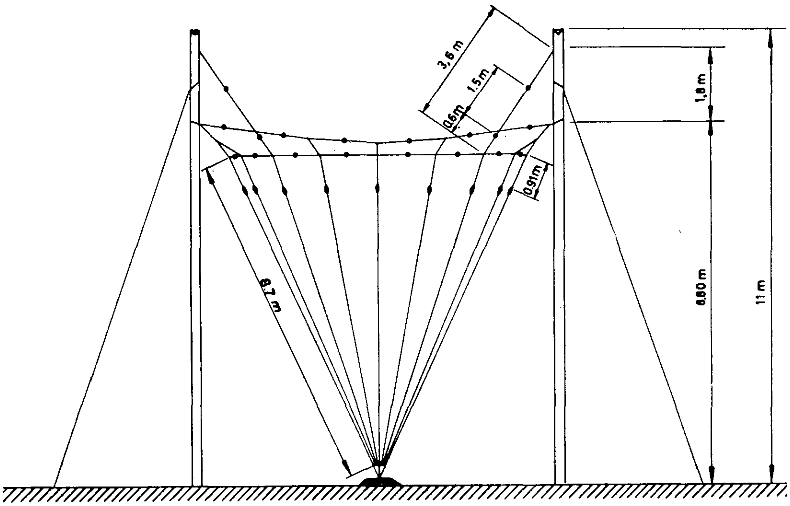

FIGURE 5

Front elevation

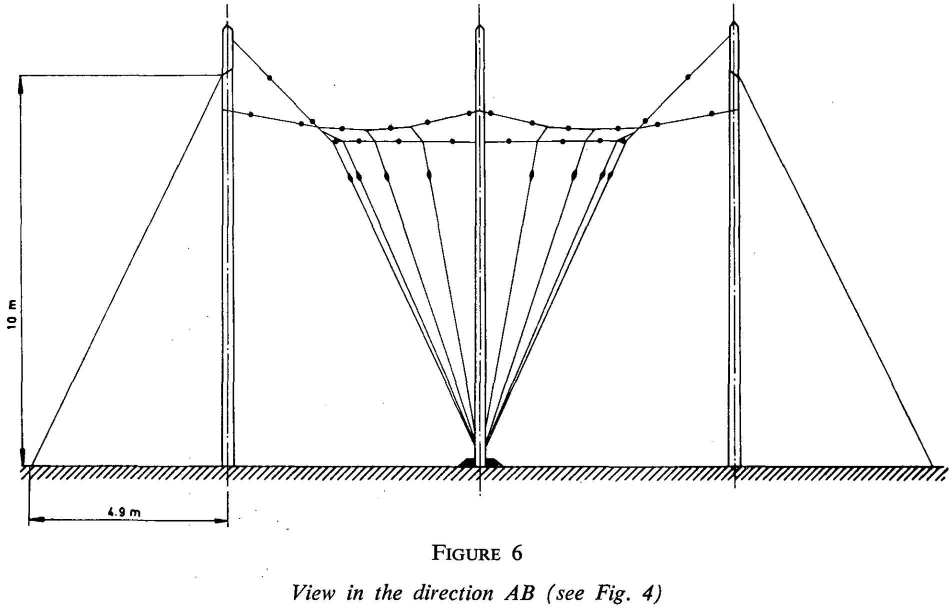

FIGURE 6

View in the direction AB (see Fig. 4)

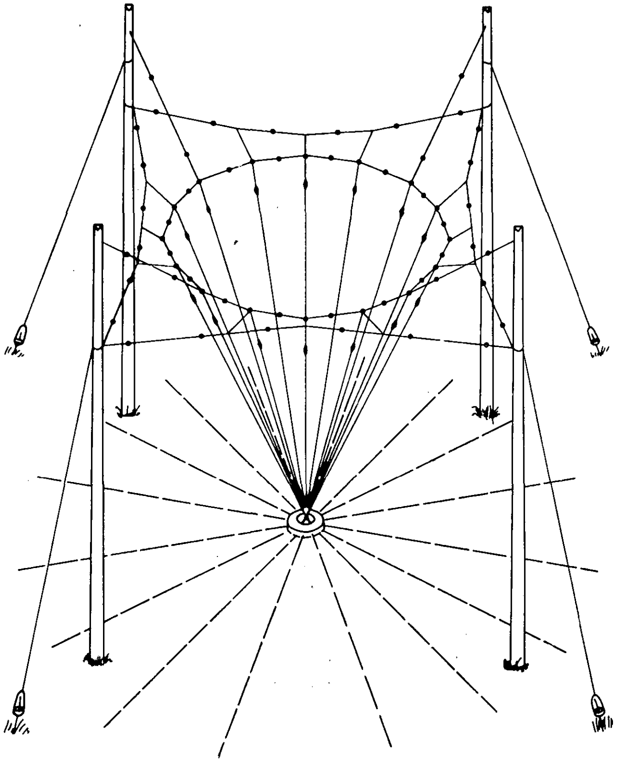

FIGURE 7

General view of antenna

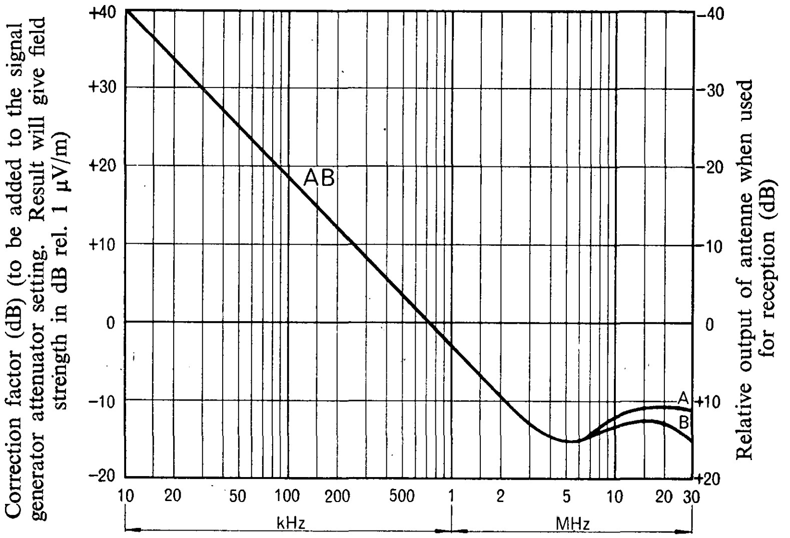

FIGURE 8

Calibration curve of inverted-cone antenna

Note.– Scale for use when measuring field strength by the substitution method (see Report 368).

A: including a specified type of cable feeder, 400 m long
B: without cable attenuation

9. Doc. VIII/70 (O.I.R.T.), 1963-1966

Radio monitoring requires antennae that, for the smallest possible dimensions, are as wide-band as possible. Non-directional antennae (e.g. for survey observations), as well as directional antennae (e.g. to eliminate interference, to increase received voltage, to determine direction), are involved.

In the following, two types of directional antennae that have been developed and applied for radio-monitoring in the frequency range 30 to 1000 MHz will be described. One type covers the range from 30 to 180 MHz and the other from 165 to 1000 MHz. In their development the fact that such antennae must be suitable both for horizontal as well as vertical polarization was respected.

9.1 *Antenna for the 30 to 180 MHz range*

This antenna is illustrated in Fig. 9. Two identical, logarithmically periodic dipole antennae are so inter-built that their polarization directions are perpendicular to each other. Each part of the antenna is fed by means of a separate cable, so that the polarization, for example, can be altered by means of simple switching.

The antenna is mounted on a suitable rotating system, so that transmissions from any direction can be received. In the following review the most important electrical properties are listed:

Frequency range:	30 to 180 MHz
Input impedance:	60 Ω, asymmetrical
Standing wave ratio:	$s = U_{max}/U_{min} \leqq 2 \cdot 5$
Antenna gain (relative to elementary dipole):	on the average about 5 dB
Polarization:	horizontal and vertical (selected by switching)
Antenna length:	about 4·6 m

9.2 *Antenna for the 165 to 1000 MHz range*

For this frequency range a new extremely wide-range antenna was developed. Its design is based on a departure from the logarithmic-periodicity principle. As with logarithmically-periodic dipole antennae, a relatively large number of dipoles fed by means of a symmetrical two-wire cable (Fig. 10) is used. The extreme ends of the dipoles lie on a monotonically rising limiting curve in contrast to the straight line in the logarithmically-periodic antenna.

A definite dependence of antenna gain on frequency is given by choice of the limiting curve. The spacing of the dipoles, the diameter as well as the characteristic impedance of the symmetrical two-wire feed-line can be so chosen, that the input impedance of the antenna has the desired value and is approximately independent of frequency.

Fig. 11 shows the antenna for the frequency range 165 to 1000 MHz. The feed-line system is covered by an epoxy-resin coat strengthened with glass-fibres. By this means the antenna is given sufficient strength and at the same time is well protected against the influences of weather.

The antenna has the following characteristics:

Frequency range:	165 to 1000 MHz
Input impedance:	60 Ω, asymmetrical
Standing wave ratio:	$s = U_{max}/U_{min} \leqq 2$
Antenna gain:	see Fig. 12
Polarization:	as desired
Radiation pattern:	see Fig. 13
Width at half-power value:	see Fig. 14

Front-back ratio

– over the range of 165 to 400 MHz:	$\geqq$ 15 dB
– over the range of 400 to 1000 MHz:	$\geqq$ 20 dB
Length:	about 1·6 m
Width:	about 0·9 m
Weight:	about 3·6 kg

The antenna gain rises with the frequency while the radiation angle in the H-plane is smaller.

By this means, the general decrease in both receiver sensitivity, as well as in the power obtainable from an antenna with rising frequency, can be compensated. The advantages of the described antenna are evident when one considers that with a logarithmically-periodic dipole antenna system of the same length in the given frequency range a constant gain of about 7 dB (relative to an elementary dipole) is barely obtainable.

This antenna is as readily transportable as it is quickly mountable and is therefore also suitable for mobile applications, e.g. for field-strength measurements or propagation research. With suitable rotation equipment, it can also be readily used in stationary radio monitoring stations. The antenna can be mounted both in a horizontal (Fig. 11) as well as in a vertical position. In stationary installations, in general, signals of arbitrary polarization from any direction can be received.

Two antennae with mutually perpendicular polarization are fixed on a rotatable mast. Each antenna has a separate lead-in cable which is led down to the receiver through the hollow mast. The polarization can be selected by means of manually operated switches or a coaxial relay.

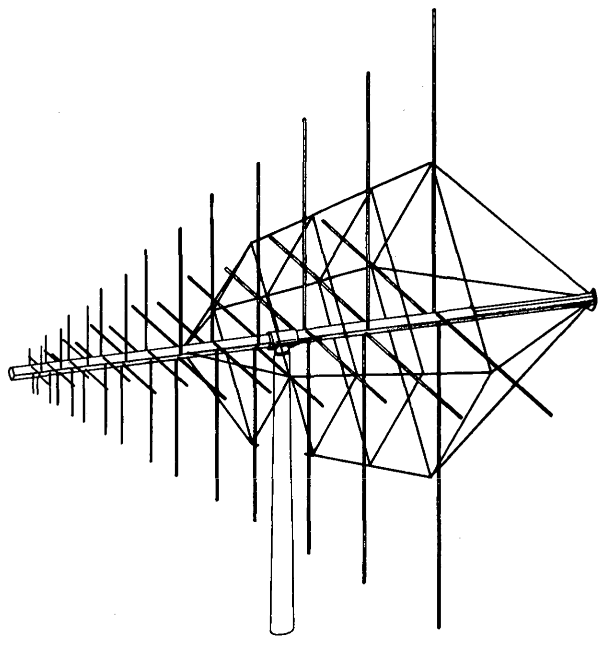

FIGURE 9

Radio monitoring antenna for the 30 to 180 MHz frequency range

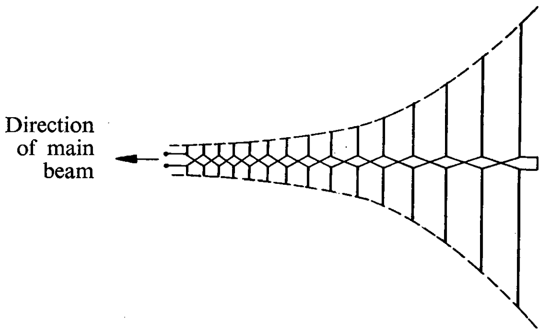

FIGURE 10
Principle of an extremely wideband dipole antenna

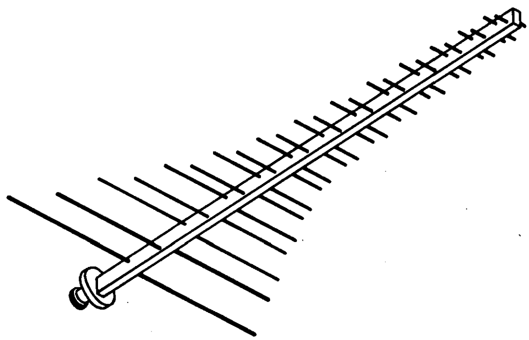

FIGURE 11
Radio monitoring antenna for the 165 to 1000 MHz frequency range

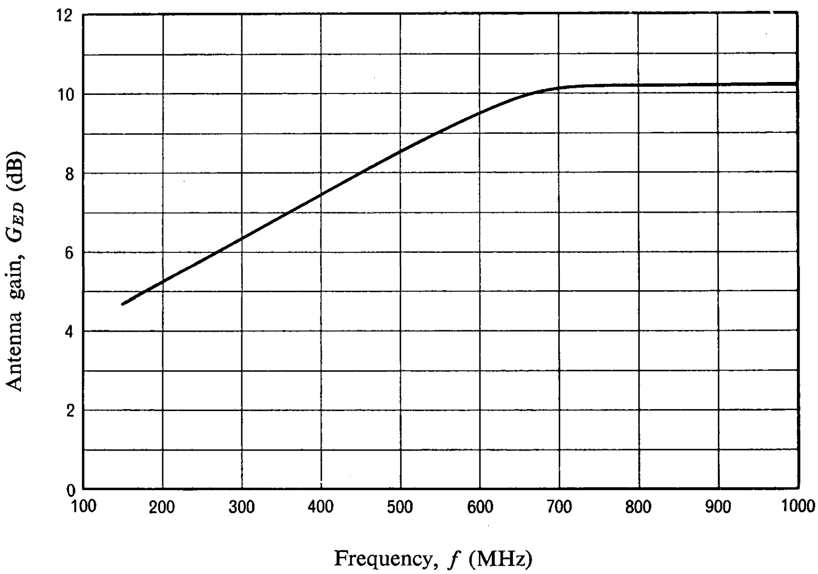

FIGURE 12
Antenna gain (relative to an elementary dipole) as a function of frequency

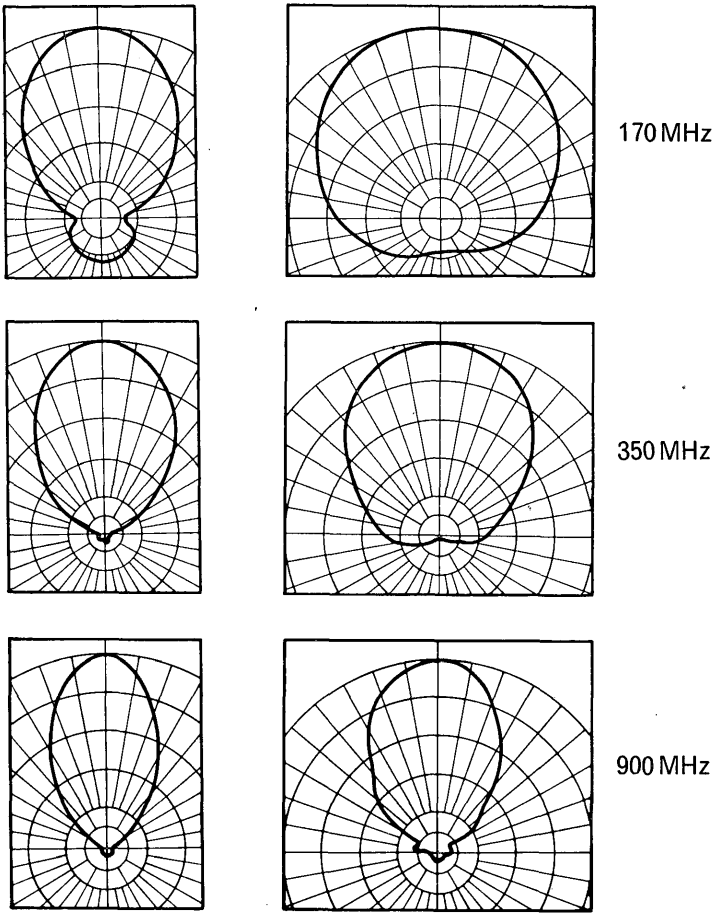

FIGURE 13

Typical directivity diagrams for the antenna shown in Figure 11

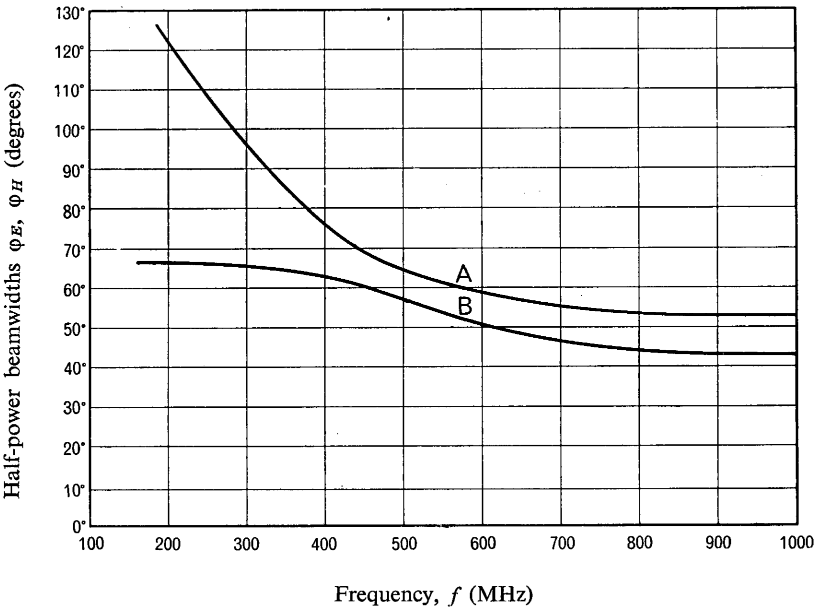

FIGURE 14

Half-width-power values for the antenna shown in Figure 11

A: H – plane

B: E – plane

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STUDY GROUP VIII

(International monitoring)

Terms of reference:

To study technical and operating problems, the solution of which depends principally on considerations of a technical character relating to monitoring stations participating in the international monitoring system with regard to:

1. in collaboration with the I.F.R.B., ways in which harmful interference can be verified and reported, in accordance with the International Telecommunications Convention and the Radio Regulations;

2. the development of methods and procedures to be used by monitoring stations in determining occupancy of the radio-frequency spectrum and the characteristics of emissions and in locating the source of an emission by direction-finding techniques;

3. specifications regarding the selection of sites, antennae and other equipment and instrumentation.

Chairman: Mr. M. AMARO VIEIRA (Portugal)
Vice-Chairman: Mr. P. BOUCHIER (Belgium)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP VIII

1. Frequency measurement

Recommendation 377-1 shows the accuracies required in the measurement of frequencies by monitoring stations.

Attention is drawn to the need to revise these accuracies should the frequency tolerances permitted by the Radio Regulations become more severe.

Report 272-1 gives details concerning certain frequency measurements.

No satisfactory procedure has yet been evolved for the measurement of frequencies in SSB, ISB and other complex types of emission (see Report 369). Question 2/VIII and Question 1/VIII therefore remain under study. The assessment of the accuracy of measurements is the subject of Study Programme 1A/VIII.

2. Field-strength measurement

Recommendation 378-1 retains the accuracies to be observed. It includes a paragraph on the calibration of equipment.

The operating requirements of monitoring stations have shown the advantage of an expeditious method of measuring field strength even if the accuracy mentioned in Recommendation 378-1 has to be waived. Recommendation 442 and Report 368 give details on the methods and equipment that should be used. Question 4/VIII on this problem, however, has been retained.

3. Bandwidth measurement

A satisfactory method has not yet been found for the measurement of occupied bandwidth by a monitoring station. The study of this problem is proposed in both Question 5/VIII and Study Programme 6A/1.

To enable monitoring stations to furnish the IFRB with bandwidth estimate, the procedure described in Recommendation 443 has been adopted provisionally in agreement with Study Group I. The relevant Report (Report 275-1) has been brought up to date accordingly.

In the study of bandwidth problems, reference should be made also to the pertinent documents of Study Group I.

4. Automatic monitoring of occupancy of the spectrum

Question 9/VIII, which remains under study, is partly answered in Recommendation 182-1 and Report 278-1.

5. Visual monitoring of the spectrum

In the absence of further replies to Question 10/VIII, Report 279 was retained unchanged.

6. Measurements at mobile monitoring stations

Report 277-1 was brought up to date.

7. Monitoring of transmissions from spacecraft

Question 6/VIII was retained. A paragraph on the measurement of power flux-density was added to Report 276-1.

8. Monitoring of sweeping-type pulse emissions

Question 7/VIII closely resembles former Question 226.

Report 367 gives a part reply to this Question. In view of the level of the interference which may be caused by this type of emission, Study Group I was asked to propose that the specifications of the necessary equipment should be examined.

9. Direction-finding at monitoring stations

Question 8/VIII was retained.

To assist monitoring station personnel, the major part of Report 372 was devoted to the question of the accuracy of bearings and positions.

10. Antennae for monitoring stations

Report 373 gives part replies to Question 11/VIII. This Report may prove extremely useful to Administrations wishing to establish new monitoring stations.

11. Monitoring in the new and developing countries

Report 371 contains detailed information on Question 12/VIII and will certainly be of great service to countries intending to establish a monitoring service.

12. Assistance to various services

This problem is the subject of Question 13/VIII and Study Programme 13A/VIII.

Report 370 describes the benefits obtained from a programme for the exchange of monitoring personnel of different countries.

Opinion 30 draws attention to the contribution which monitoring stations could make to the rational use of the spectrum.

13. Identification of stations

Recommendation 379-1 and Report 280-1 contain replies to Question 14/VIII. For certain complex types of emission no suitable method of transmitting the identification signal has yet been found. Question 14/VIII has therefore been retained.

Opinion 29 asks that the Radio Regulations provision on the transmission of identification signals be followed more strictly.

The IFRB was asked to undertake publication of the list referred to in Opinion 11, using the information in its possession. This list, brought up to date by information provided by Administrations, would be extremely useful in solving certain cases of interference.

14. Expansion of the monitoring system

Report 282-1 shows the world distribution of monitoring stations which participate in the international monitoring system and, in conjunction with Resolution 15, draws attention to the advantages of extending the coverage of the system.

15. Identification of sources of interference

Question 15/VIII and Report 281 led to the preparation by the C.C.I.R. Secretariat of a magnetic tape giving information on various classes of emission and on a number of cases of interference.

Following the adoption of Resolution 16-1, mentioned in the section below, Question 15/VIII and Report 281-1 were amended to facilitate the drafting of a handbook dealing with all aspects of concern to monitoring stations.

16. Handbook for monitoring stations

The expansion on a world-wide scale of the international monitoring system and the problems raised by such Questions as 11/VIII, 12/VIII and 15/VIII showed the need to prepare a handbook for monitoring stations which would assist Administrations, particularly those of the new and developing countries, in the establishment and operation of these stations.

Resolution 16-1, under which a number of Administrations undertook to prepare this handbook in collaboration with the C.C.I.R. Secretariat and which lists the various chapters of the handbook, was therefore adopted.

17. Problem of concern to the new and developing countries

This new section of § 2.2.2 in Resolution 33 will deal with questions and problems of concern to the new and developing countries.

Some aspects of this matter are mentioned above. It is extremely difficult, if not impossible, to deal with these aspects separately, as certain questions of concern to some countries may, for various reasons, be of less interest to others.

With this proviso, we would draw attention to the following:

Recommendations: 182-1, 378-1, 379-1, 442, 443;

Reports: 272-1, 275-1, 280-1, 368, 370, 371, 372, 373;

Question: 2/VIII;

Opinions: 29, 30.

RESOLUTION 15

EXTENSION OF THE INTERNATIONAL MONITORING SYSTEM TO A WORLD-WIDE SCALE

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

CONSIDERING

(a) that Recommendation No. 5 of the Administrative Radio Conference, Geneva, 1959, stresses the urgent need for improvement in the international monitoring system and invites Administrations to make every effort to develop monitoring facilities;

(b) that there are still wide areas of the world where the facilities available to the international monitoring system are inadequate or non-existent;

(c) that it is of utmost importance, to satisfy the needs of the I.F.R.B. laid down by the Radio Regulations, that all countries having domestic monitoring facilities make them available for international monitoring to the maximum possible extent;

(d) that it is recognized that certain stations may participate in only a limited part of the whole field of monitoring;

(e) the importance, for the safety of life at sea and in the air, of the international monitoring system in ensuring the correct use of the radio-frequency spectrum by the mobile services;

UNANIMOUSLY DECIDES

1. that all Administrations now participating in the international monitoring system should be urged to continue to do so to the maximum extent possible;

2. that Administrations, who do not at present participate in the international monitoring system, should be urged to make monitoring facilities available to that system, in accordance with Article 13 of the Radio Regulations, Geneva, 1959;

3. that Administrations, located in those areas of the world where monitoring facilities are inadequate (as indicated by Report 282–1), should be urged to promote the establishment of monitoring stations for their own use and make them available for international monitoring, in accordance with Article 13 of the Radio Regulations, Geneva, 1959;

4. that Administrations should monitor radio stations in the mobile services systematically, in particular those stations serving maritime and aeronautical needs.

RESOLUTION 16-1

HANDBOOK FOR MONITORING STATIONS

(Questions 12/VIII and 15/VIII)

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

CONSIDERING

(a) the ever-growing importance of monitoring stations, both for the needs of the international monitoring system and for the Administrations' own requirements;

(b) the ever-increasing difficulties encountered by Administrations in collecting the information required for the establishment or modernization of monitoring stations;

(c) Question 12/VIII and, in particular, the importance of compiling useful data to enable new and developing countries to set up their own stations and to take an active part in the international monitoring system;

(d) Question 15/VIII and the urgent need for the collection of visual and/or aural records of the typical characteristics of various classes of interfering radiations as an aid to personnel at stations in the international monitoring system;

UNANIMOUSLY DECIDES

1. that the C.C.I.R. Secretariat should:

1.1 publish a handbook for monitoring stations, containing detailed information on the different chapters indicated in Annex I;

1.2 publish any complementarly information (for example, magnetic tape recordings), which cannot be included in the volumes of the handbook;

2. that drafting groups be set up to prepare the various chapters of the handbook, in cooperation with the C.C.I.R. Secretariat and, if necessary, the I.F.R.B., following the procedure mentioned in Annex II;

3. that Administrations, Private Operating Agencies and International Organizations be asked to supply to the C.C.I.R. Secretariat any useful information required for the accomplishment of the task specified in § 1.

ANNEX I

CHAPTERS OF THE HANDBOOK

1. Purpose of monitoring and its field of activity

2. Siting of monitoring stations

3. Buildings and auxiliary installations

3.1 Buildings

3.2 Power supplies and other installations

4. Antennae

4.1 Different types of antennae

4.2 Layout of antennae

4.3 Transmission lines and distribution equipment

5. Receivers

5.1 Monitoring receivers

5.2 Special purpose receivers

6. Frequency measurement

6.1 Standards

6.1.1 standards comparisons

6.2 Methods of measurement

6.3 Precision of measurements

6.4 Measuring equipment

7. Field strength and power flux-density measurements

7.1 Choice of measurement sites for fixed installations

7.2 Measurement cubicles

7.3 Measurement methods

7.3.1 normal methods

7.3.2 expeditious methods

7.4 Calibration of measuring instruments

7.5 Precision of measurements

7.6 Long-term measurements (including field-strength recording and its analysis)

8. Monitoring of spectrum occupancy

8.1 Manual monitoring

8.2 Automatic monitoring

9. Measurement of the bandwidth of emissions

10. Measurement of modulation (according to the class of emission)

10.1 Measurement of the depth of modulation

10.2 Measurement of the frequency-deviation

11. Special measurements for television emissions

12. Radio direction-finding

12.1 Site characteristics

12.2 Types of equipment

12.3 Precision of bearings

13. Identification

13.1 Identification of transmitters

13.2 Identification of classes of emission

14. Identification and location of sources of interference

14.1 Interference caused by radio stations

14.2 Interference from other sources

15. Mobile monitoring stations

15.1 Field of activity

15.2 General characteristics of equipment

15.3 Specifications for the different types of measurement

15.3.1 choice of sites for field-strength measurements

16. Minimum essential equipment for a monitoring station

17. Organization of operation in monitoring stations

17.1 Examples of organization

17.2 Examples of preparation of monitoring reports and compilation of monitoring data

18. Staff
18.1 Recruitment
18.2 Training

19. Participation in the international monitoring system
19.1 Cooperation with the I.F.R.B
19.2 Cooperation between the monitoring stations of different countries
19.3 Service documents of the I.T.U

ANNEX II

ARRANGEMENTS FOR PREPARING THE HANDBOOK

1. To expedite publication of the Handbook, it will be divided into several volumes (one for each chapter) and these volumes will be issued as and when they are ready, even though this may sometimes mean departing from the order indicated in Annex I. Each volume will be in loose-leaf form, so that the Handbook may easily be brought up to date.

2. The C.C.I.R. Secretariat is requested to write to Administrations, Private Operating Agencies and International Organizations, asking them to submit relevant information and the names of the persons capable of participating in the drafting of the various chapters.

3. The drafting group for each chapter, or group of chapters, will consist of a coordinator responsible for the draft, assisted, so far as possible, by collaborators belonging to diffferent Administrations, Private Operating Agencies or International Organizations.

4. For each chapter of the Handbook, the C.C.I.R. Secretariat will assemble the information received and prepare an outline on the basis of this documentation and that already published.

5. This outline and the relevant documentation will be sent by the C.C.I.R. Secretariat to the coordinator of the chapter and his assistant authors.

6. The coordinator and his assistant authors will prepare, in collaboration with the C.C.I.R. Secretariat, a final text for publication.

7. Each drafting group will work to the maximum extent possible by correspondence.

8. The following Administrations, the I.F.R.B. and International Organizations shall designate, within three months after the XIth Plenary Assembly of the C.C.I.R., the individuals responsible for the drafting of the various chapters:

Chapter 1: Portugal
Chapter 2: U.S.A.
Chapter 3: U.S.A.
Chapter 4: Canada
Chapter 5: Canada
Chapter 6: Federal Republic of Germany
Chapter 7: U.S.A.
Chapter 8: France
Chapter 9: Japan
Chapter 10: Portugal
Chapter 11: E.B.U.
Chapter 12: Portugal
Chapter 13: U.S.A.
Chapter 14: United Kingdom
Chapter 15: Italy

Chapter 16: Federal Republic of Germany

Chapter 17: France

Chapter 18: Canada

Chapter 19: I.F.R.B.

9. The C.C.I.R. Secretariat will attempt to obtain from Administrations, Recognized Private Operating Agencies and International Organizations, the designation of the collaborators indicated in § 2 for the various chapters.

OPINION 11

LIST OF STATIONS USING SPECIAL MEANS OF IDENTIFICATION

(Question 14/VIII)

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

CONSIDERING

(a) that the Radio Regulations, Geneva, 1959, set forth requirements for transmission of identifying signals by radio stations;

(b) that certain types of radio stations are exempted from the necessity of having a call sign from the international series, for example, stations which are identified by other means;

(c) that many stations, using complex or special types of emission, cannot be identified by ordinary means;

(d) that the monitoring stations participating in the international monitoring system need to be supplied with all the available information on means of identification used by radio stations;

IS UNANIMOUSLY OF THE OPINION

1. that the I.F.R.B. should be asked to prepare, on the basis of information received from Administrations, the list of stations which use special identification means; this list to contain the identifying signal, frequency, method of identification used, time of identification, and other pertinent information;

2. that this list should be kept up-to-date by appropriate supplements.

QUESTION 1/VIII *

FREQUENCY MEASUREMENTS AT MONITORING STATIONS

The C.C.I.R., (1956 – 1963)

CONSIDERING

that it is desirable to improve the accuracy, speed and convenience of frequency measurements, particularly under conditions of fading, interference, carrier instability, etc., including the case of suppressed or keyed carriers;

* Formerly Question 252(VIII).

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the accuracy and speed of frequency measurements which can be accomplished at monitoring stations, especially under the conditions set forth above;

2. what are the difficulties in meeting the required accuracy (Recommendation 377-1), due to limitations set by:

2.1 the measuring equipment;

2.2 propagation effects such as fading;

2.3 interference due to other transmissions;

2.4 the type of modulation, particularly for wideband transmissions in the frequency range 500 MHz to 10 GHz;

3. to what extent can errors be usefully reduced in practice by statistical processing of the measurement data when measurements are taken at successive times or under different conditions?

STUDY PROGRAMME 1A/VIII *

METHOD OF DETERMINING THE AVERAGE ACCURACY OF FREQUENCY MEASUREMENTS AT MONITORING STATIONS

The C.C.I.R., (1965)

CONSIDERING

(a) that Recommendation 377-1 establishes the accuracy with which monitoring equipment and frequency measurement procedures should be capable of carrying out such measurements;

(b) that in the course of normal operation of a monitoring station, it is impracticable to determine the accuracy with which each measurement has been effected;

(c) that the accuracy of the measurement depends, not only on the accuracy of the standard used, but also on the measurement equipment, the method used and the stability of the signal level;

(d) that it would be most useful to have uniform methods for determining the average accuracy of the measurements made with a given equipment during normal operation of a monitoring station;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of practical methods for assessing the highest and the average accuracy of frequency measurements in the course of routine operation of a monitoring station;

2. determination of the parameters to be borne in mind when evaluating this accuracy, taking into account both stable signals and signals subject to fading.

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* Formerly Study Programme 252A (VIII).

QUESTION 2/VIII *

MEASUREMENT OF FREQUENCIES OF SINGLE-SIDEBAND, INDEPENDENT-SIDEBAND AND OTHER COMPLEX EMISSIONS

The C.C.I.R., (1965 – 1966)

CONSIDERING

(a) that the growing use of single-sideband, independent-sideband and other types of complex emission makes it increasingly difficult for monitoring stations to measure emission frequencies;

(b) that, consequently, there is an ever more urgent need to find methods and equipment capable of performing these tasks,

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the methods recommended for determining, at monitoring stations, the centre frequency of the different classes of complex emission;

2. what are the most suitable specifications for the equipment required?

QUESTION 3/VIII **

FIELD-STRENGTH MEASUREMENTS AT MONITORING STATIONS

The C.C.I.R., (1965)

CONSIDERING

(a) that Recommendation 378-1 – Accuracy of field-strength measurements by monitoring stations – does not cover all aspects of the problem, and that it recommends that studies, relating to methods and equipment for use at monitoring stations, should be continued;

(b) that the importance of collecting comparable field-strength data for the purpose of making propagation studies is increasing;

UNANIMOUSLY DECIDES that the following question should be studied:

1. taking into account the previous work of the C.C.I.R. in this field, what are the preferred equipment and the preferred methods for measuring the field-strength of emissions for propagations studies at monitoring stations;

among other factors the following should be studied:

– the methods for measuring the field strength,

– the measuring and recording equipment,

– the total frequency range,

– the calibrating equipment,

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* This Question replaces Question 295.

** Formerly Question 293(VIII).

QUESTION 2-1/VIII

PROCEDURES FOR DETERMINATION OF THE CENTRE FREQUENCY OF AN EMISSION *

(1968)

The C.C.I.R.,

CONSIDERING

(a) the growing use of single-sideband, independent-sideband and, in particular, complex and multi-channel frequency-division emissions;

(b) the difficulty in assessing the corresponding centre frequency for these emissions;

(c) that the knowledge of this centre frequency is fundamental in solving problems of harmful interference, in determining occupancy of the spectrum and in verifying compliance with the frequency tolerances prescribed in the Radio Regulations;

(d) that, consequently, there is an ever more urgent need to find procedures to solve the various problems involved;

DECIDES that the following question should be studied:

1. what are the procedures to be recommended to enable the determination of the centre frequency for the different classes of emission;

2. what are the most suitable procedures to be adopted and what are the specifications for the additional equipment required at transmitting stations and at monitoring stations?

STUDY PROGRAMME 2-1A/VIII

PROCEDURE CONCERNING FREQUENCY MEASUREMENTS, CHANNEL IDENTIFICATION AND NOTIFICATION OF FREQUENCY ASSIGNMENTS OF SINGLE-SIDEBAND, INDEPENDENT-SIDEBAND, COMPLEX EMISSIONS AND MULTI-CHANNEL EMISSIONS USING FREQUENCY-DIVISION MULTIPLEX

(1968)

The C.C.I.R.,

CONSIDERING

(a) the problem in assessing the centre frequency * in relation to a characteristic frequency which can be measured, to permit comparison between the centre frequency and the assigned frequency;

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* The centre frequency of the bandwidth occupied by a complete emission (e.g., when all the channels are operating).

(b) that the centre frequency of the occupied band is, in many cases, not a characteristic frequency and consequently the centre frequency is not directly measurable;

(c) that in the case of multi-channel emissions, difficulties occur in relating the channels in operation with a given emission and their position in the spectrum with respect to the corresponding centre frequency, especially when some channels are idle;

(d) that the problem cannot be solved solely by new methods at monitoring stations but must be solved primarily by procedures to be implemented at the transmitting stations;

DECIDES that the following studies should be carried out:

1. definition of basic procedures to be adopted at transmitting stations to enable:

1.1 determination of the centre frequency in relation to a characteristic frequency which can be measured (for instance, transmission at given periods of a characteristic frequency in each channel);

1.2 identification of each operating channel and its position in relation to the assigned frequency (for instance, by the use of a code transmitted during the period for station identification);

2. determination of methods to be recommended for finding the centre frequency at monitoring stations, by measuring a characteristic frequency of the emission in conformity with procedures that could be adopted in response to § 1, to permit comparison with the assigned frequency;

2.1 specification of the most suitable equipment required;

3. formulation, as a consequence of the above studies, of the necessary modification to be recommended for the procedure for the notification of frequency assignments as prescribed in the Radio Regulations.

– the methods for analysing the records,
– the most effective form of presentation and distribution of these data for the benefit of various bodies, for example the I.F.R.B.,

2. what are the most useful programmes of propagation studies in the different frequency ranges that can be carried out at monitoring stations, bearing in mind:
– the needs of the I.F.R.B., Study Groups of the C.C.I.R. and other bodies,
– the various distances and the particular paths over which propagation data are required;

3. what are the equipment and methods to be preferred for measuring the field-strength of emissions:
– with interrupted carrier,
– with reduced carrier,
– with other types of signal, including television signals;

4. what are the equipment and methods to be preferred for measuring the field-strength of emissions of the types given in § 3, in the presence of noise and interference?

QUESTION 4/VIII *

EXPEDITIOUS METHOD OF DETERMINING FIELD STRENGTH AT MONITORING STATIONS

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that the accuracies prescribed in Recommendation 378-1 are not always necessary in monitoring observations, an accuracy better than $\pm$ 6 dB being sufficient for such a purpose, in the frequency band 12 kHz to 30 MHz;
(b) that, according to studies made to date (see Recommendation 442 and Report 368), equipment answering this purpose can be obtained;
(c) that it would be desirable to improve the existing methods for the expeditious measurement of field strength;

UNANIMOUSLY DECIDES that the following questions should be studied:

1. what type of equipment, including those types described in Report 368, is the most suitable for the expeditious measurement of field strength at monitoring stations;

2. what specifications should be adopted for the performance of the equipment (antenna, transmission line, receiver and calibrating source) ?

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* Formerly Question 291(VIII).

QUESTION 5/VIII *

BANDWIDTH MEASUREMENTS AT MONITORING STATIONS

The C.C.I.R., (1965 – 1966)

CONSIDERING

(a) that determination of the occupied bandwidth of an emission, by the method of measuring total power and out-of-band power, in accordance with the present definition of occupied bandwidth (see No. 90 of the Radio Regulations, Geneva, 1959), is not generally applicable to measurements made at a distance from the transmitter;

(b) that the I.F.R.B. requires practical optimum standards concerning bandwidth measurements at monitoring stations;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the most suitable equipment and methods for bandwidth measurement at monitoring stations of the various classes of emission, both on stable signals and signals subject to fading and in the presence of noise and interference;

2. while awaiting the development of such a suitable method, what is the accuracy obtainable at monitoring stations when using the bandwidth estimation procedure described in Recommendation 443, when compared to measurements made at or near the transmitter by the methods described in Recommendation 327-1 ?

QUESTION 6/VIII **

MONITORING AT FIXED MONITORING STATIONS OF RADIO EMISSIONS FROM SPACECRAFT

The C.C.I.R., (1965)

CONSIDERING

(a) that the rapid advances in recent years in space technology, including the successful launching of earth satellites, portend greatly expanded activity in outer space, including the probable establishment of " space platforms ";

(b) that radio will play a major part in these space activities as regards communication, navigation and data collection and transmission;

(c) that " space platforms " might find a variety of uses in the telecommunication field;

* This Question replaces Question 294.

** Formerly Question 290(VIII).

(d) that the accurate measurement at a fixed monitoring station of frequency, spectrum occupancy, power flux-density at the earth's surface and certain other technical characteristics of emissions from transmitters on the spacecraft and platforms, will tend to be more difficult than on fixed or relatively slow moving sources of emission on or near the earth,

UNANIMOUSLY DECIDES that the following question should be studied:

1. to what extent will the techniques of measurement, from fixed monitoring stations on the earth, of emissions from spacecraft, differ from those for emissions originating from or near the earth;

2. what are the requirements for specialized equipment or associated facilities for performing frequency, spectrum occupancy, power flux-density at the surface of the earth and other measurements of emissions from spacecraft;

3. what practical means can be devised for identification, by monitoring stations, of emissions from specific spacecraft ?

Note. – It would be most desirable that results of measurements of field strength or power flux-density made by monitoring stations be assembled by the respective Administrations, to assist in propagation studies made by other Study Groups of the C.C.I.R.

QUESTION 7/VIII *

MONITORING OF SWEEPING-TYPE PULSE EMISSIONS

The C.C.I.R., (1962 – 1966)

CONSIDERING

(a) the increasing use being made of very short-duration pulse emissions, which may be modulated in various ways and which are frequency-swept over wide ranges of the radio-frequency spectrum;

(b) that these emissions may, in some instances, be sources of interference to other transmissions, requiring identification and measurement by monitoring stations to assist in resolving such interference;

(c) that special facilities and techniques are required by monitoring stations to receive, measure and identify signals of this type;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what is the extent of interference caused by sweeping-type pulse transmissions as they pass through, or temporarily rest on or near, the frequency of other transmissions;

2. what are the preferred facilities and techniques to permit reception and measurement by monitoring stations of these sweeping-type pulse emissions;

3. how may these sweeping-type pulse transmissions be identified by monitoring stations ?

* Formerly Question 226(VIII).

QUESTION 8/VIII *

DIRECTION-FINDING AT MONITORING STATIONS

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

CONSIDERING

(a) that direction-finding measurements in some cases have very great significance for Administrations and the I.F.R.B. in the investigation of harmful interference and in their concern with efficient use of the radio-frequency spectrum;

(b) that, while the techniques of direction-finding are well known, the methods and procedures best suited to the international monitoring system are not established;

(c) that the accuracy of bearings may be improved by certain procedures, e.g., by the statistical treatment of multiple bearings or by taking reference bearings on known stations;

UNANIMOUSLY DECIDES that the following question should be studied:

what methods of direction-finding and what procedures for improving the accuracy of bearings can be recommended for:

- fixed monitoring stations;
- mobile monitoring stations ?

QUESTION 9/VIII **

AUTOMATIC MONITORING OF OCCUPANCY OF THE RADIO-FREQUENCY SPECTRUM

The C.C.I.R., (1956 – 1963)

CONSIDERING

(a) that the rapidly increasing demand for radio services continues to require the most efficient use of the radio-frequency spectrum;

(b) that the most efficient use of the spectrum can be made only when its occupancy is known;

(c) that automatic monitoring is recommended as a valuable aid to determining the occupancy of the spectrum; and the desirable characteristics of such equipment have been already recommended in Recommendation 182-1;

(d) that it is desirable to make further studies of equipment characteristics and to determine the means whereby the greatest benefit may be derived from automatic monitoring records;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what is the accuracy of automatic monitoring equipment in determining frequency, bandwidth and field strength;

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* Formerly Question 254(VIII).

** Formerly Question 255(VIII).

2. what is the capability of automatic monitoring equipment in determining signal-to-noise ratios;

3. what are the best means of analysing and evaluating automatic monitoring records, both singly and collectively;

4. is it possible to analyse present records by automatic means and, if not, what modifications are necessary to enable this to be done ?

QUESTION 10/VIII *

VISUAL MONITORING OF THE RADIO-FREQUENCY SPECTRUM

The C.C.I.R., (1959)

CONSIDERING

(a) that every useful means of monitoring observation and measurement should be employed at monitoring stations, including visual methods employing a radio-frequency spectroscope;

(b) that a panoramic view of a portion of the radio-frequency spectrum can be presented on a cathode-ray tube by the employment of suitable sweep circuits in the radio receiver or in an associated panoramic adapter;

(c) that the simultaneous presentation of broad ranges of the spectrum on one or more cathode-ray tubes would provide for a rapid determination of spectrum occupancy, frequency, amplitude and harmonic content (if one or more octaves are presented) of individual signals and broadband coverage characteristics of signals, including interference;

(d) that, although panoramic adapters have been employed to some extent in monitoring stations as an adjunct to aural monitoring, it appears that more information can be obtained visually by monitoring observers, particularly in broadband visual presentation of the spectrum;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the preferred equipment and the preferred methods for visual monitoring of broad ranges of the radio-frequency spectrum with regard to:

1.1 receivers and associated frequency-sweep circuits;

1.2 cathode-ray tubes (including practicable size);

1.3 antennae and associated broadband amplifiers and impedance-matching circuits;

2. what radio-frequency ranges can be presented simultaneously on one or more cathode-ray tubes of a spectroscope, taking into consideration the frequency characteristics of the antennae, amplifiers and receivers to allow relative comparisons throughout the portion of the spectrum under visual observation;

3. what adaptation of circuitry of the equipment specified in § 1 would be required for a temporary increase in the resolution of the spectroscope;

4. what are the desirable operating methods and techniques to obtain maximum benefit from visual monitoring with a radio-frequency spectroscope, either when used alone or when used as an adjunct to aural monitoring ?

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* Formerly Question 191(VIII).

QUESTION 11/VIII *

ANTENNAE FOR MONITORING STATIONS

The C.C.I.R., (1965)

CONSIDERING

(a) that the effectiveness of a monitoring station, in providing adequate surveillance over the radio-frequency spectrum, is determined to a major extent by the electrical characteristics of the available monitoring antennae;

(b) that substantial progress has been made in recent years in the development of broadband antennae having improved characteristics as regards frequency coverage, directivity and gain;

(c) that the anticipated future need for providing monitoring station facilities to permit observations and measurements of transmissions from spacecraft will require specialized antennae, taking into account the relatively weak signals involved and the high antenna directivity required;

UNANIMOUSLY DECIDES that the following question should be studied:

1. to what extent do currently available antennae fulfil the requirements of the monitoring stations, taking into account such aspects as: means of varying both horizontal and vertical directivity, gain, space limitations;

2. what are the desirable characteristics of antenna systems for monitoring in the various frequency bands of interest and for various propagation modes;

3. in which areas should further antenna development work be directed in an effort to improve monitoring antenna characteristics (for instance: directivity, bandwidth, dimensions, possibilities of orientation) ?

QUESTION 12/VIII **

MONITORING SERVICES IN THE NEW AND DEVELOPING COUNTRIES

(Question No. 2 of the Plan Sub-committee for Asia, Geneva, 1963)

The Regional Plan Committee for Asia, (1963)

CONSIDERING

(a) the importance of radio-frequency monitoring in the improvement of general operation of the expanding radio services;

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* Formerly Question 292(VIII).

** Formerly Question 275(VIII).

(b) the need for establishing more radio monitoring stations in the various parts of the world, which up to now have had very little or no radio monitoring services capable of participating in the international monitoring services;

REQUESTS the C.C.I.R. to study the following question:

1. which radio monitoring services should be started by the new and developing countries in this field;

2. what guidance can be given in the establishment and organization of a radio monitoring service;

3. what facilities should the monitoring equipment provide and what are the suitable characteristics for such equipment?

Explanatory note: There is a great need for starting some radio monitoring service for conservation of spectrum space, for the avoidance of harmful interference and for finding new frequencies which the new countries need for their radio services. Guidance in these matters would be helpful.

OPINION 29

TYPES AND METHODS OF ASSISTANCE BY MONITORING STATIONS TO THE OPERATION OF VARIOUS RADIO SERVICES

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

CONSIDERING

the assistance that the international monitoring system can render in promoting rational use of the radio-frequency spectrum;

IS UNANIMOUSLY OF THE OPINION that

the Administrations, C.C.I.R. Study Groups concerned and the I.F.R.B. should be asked to suggest any technical studies to be initiated and those which should be expanded, to provide improved assistance by the international monitoring system to Administrations and to the I.F.R.B.

QUESTION 13/VIII *

TYPES AND METHODS OF ASSISTANCE BY MONITORING STATIONS TO THE OPERATION OF VARIOUS RADIO SERVICES

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

CONSIDERING

(a) that monitoring stations in the international monitoring system exist for the purpose of increasing the effectiveness of radiocommunications throughout the various radio services;

* Formerly Question 259(VIII).

(b) that techniques progress so rapidly, particularly in new fields such as space telecommunications, that conditions may exist whereby neither the Administration concerned nor the international monitoring system may be aware of the full potentialities of monitoring functions for rendering assistance to radio services;

(c) that the attention of all C.C.I.R. Study Groups and all Administrations should be called to available monitoring functions, for the purpose that they be alerted to keep the international monitoring system advised of types and methods of assistance that could be initiated or expanded to use full potentialities of that system;

UNANIMOUSLY DECIDES that the following question should be studied:

what monitoring functions, not now being performed, or not being rendered to full capability, could be initiated or expanded to provide improved assistance to Administrations or to the I.F.R.B.?

STUDY PROGRAMME 13A/VIII *

TYPES AND METHODS OF ASSISTANCE BY MONITORING STATIONS TO THE OPERATION OF VARIOUS RADIO SERVICES

The C.C.I.R., (1965)

CONSIDERING

(a) that monitoring stations of various Administrations work towards a common end;

(b) that it is desirable for monitoring stations to benefit from one another's experience;

(c) that it would be useful, both for the needs of Administrations and those of the I.F.R.B., to find a practical way of keeping monitoring stations of each Administration informed of the methods and new equipment adopted by monitoring stations of other Administrations;

(d) Question 12/VIII and the value of enabling the new and developing countries to obtain promptly the technical information they require in connection with installing and improving a monitoring station;

UNANIMOUSLY DECIDES that the following studies should be carried out;

1. the best means of expediting the exchange of technical information among monitoring stations;
2. improvement in the cooperation among monitoring stations;
3. means of fostering the exchange of bibliographical material among monitoring stations.

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* Formerly Study Programme 259A(VIII).

OPINION 30

IDENTIFICATION OF RADIO STATIONS

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

CONSIDERING

(a) that, by Article 19, Section I, of the Radio Regulations, Geneva, 1959, transmissions without identification or with false identification are prohibited;

(b) that monitoring stations report that many transmissions are made without identification;

IS UNANIMOUSLY OF THE OPINION that

Administrations should follow more strictly the provisions referred to under § (*a*).

QUESTION 14/VIII *

IDENTIFICATION OF RADIO STATIONS

The C.C.I.R., (1953 – 1959 – 1963)

CONSIDERING

(a) that Article 19, Section I of the Radio Regulations, Geneva, 1959, requires that the identifying signal be transmitted by methods which, in accordance with C.C.I.R. Recommendations, do not need special terminal equipment for reception;

(b) that special methods for identifying certain complex classes of emission have been evolved (Recommendation 379-1 and Report 280-1);

(c) that, however, there may be now, or in the future, some classes of emission to which the presently recommended methods of identification cannot be applied satisfactorily;

UNANIMOUSLY DECIDES that the following question should be studied:

1. which are the classes of emission that cannot be identified by the methods of identification recommended by the C.C.I.R. or set forth in the Radio Regulations, Geneva, 1959;

2. what satisfactory methods can be evolved for the identification of such emissions?

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* Formerly Question 256(VIII).

QUESTION 15/VIII *

IDENTIFICATION OF SOURCES OF INTERFERENCE TO RADIO RECEPTION

The C.C.I.R., (1959 – 1963 – 1966)

CONSIDERING

(a) that interference-causing radiations have individual characteristics which, when observed aurally or visually, often enable an experienced monitoring observer to identify the type of equipment producing the radiations;

(b) that a list of all electrical and electronic equipment, which might at times cause radio interference, would include practically every device that uses electricity;

(c) that it would be helpful in the solution of interference problems, for both monitoring observers and radio station operators to compare interfering signals with reference information of individual signal characteristics to permit rapid identification of those signals;

(d) that the individual characteristics mentioned in § (c) might include, but not be limited to: frequency range, distance range, on-off cycles, time of occurrence, characteristic note or tone, frequency stability, normal bandwidth, type of signal as viewed on oscilloscope or panoramic receiver, type of source equipment and cause of the radiation;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the preferred methods and forms of listing, by written description, magnetic tape recording or pictorial presentation, as appropriate, information on the individual characteristics of all observed types of interfering radiations, produced by radio emissions or by electrical equipment;

2. what uniform standards of measurement should be adopted for the collection of data to be sent to the C.C.I.R. Secretariat for the preparation of Chapter 14 (and its Annexes) of the Handbook referred to in Resolution 16–1.

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* This Question replaces Question 257.

LIST OF DOCUMENTS CONCERNING STUDY GROUP VIII

(Period 1963-1966)

Doc.	Origin	Title	Reference
VIII/1	United States of America	Types and methods of assistance by monitoring stations to the operation of various radio services	Q. 259
VIII/2	United States of America	Revision of S.P. 207(VIII). Bandwidth measurements by monitoring stations	S.P. 207
VIII/3	United States of America	Draft Report. Monitoring services in the new and developing countries	Q. 275
VIII/4	Portugal	Types and methods of assistance by monitoring stations to the operation of various radio services	Q. 259
VIII/5	United States of America	Direction-finding at monitoring stations	Q. 254
VIII/6	United States of America	Antennae for monitoring stations	Q. 258
VIII/7	United States of America	Proposed modification to Rec. 377. Accuracy of frequency measurements at monitoring stations	Rec. 377
VIII/8	United States of America	Proposed modification to Rec. 379. Identification of radio stations	Rec. 379
VIII/9 and Corr.1	United States of America	Proposed modification to Report 272. Frequency measurements at monitoring stations	Rep. 272
VIII/10	United States of America	Proposed modification to Report 276. Monitoring of emissions from spacecraft at fixed stations	Rep. 276
VIII/11	United States of America	Proposed modification to Report 280. Identification of radio stations	Rep. 280
VIII/12	United States of America	An expeditious method of determining field strength in the international monitoring system	Q. 253
VIII/13	United Kingdom	Proposed modification to Report 275. Bandwidth measurement by monitoring stations	Rep. 275
VIII/14	United Kingdom	Identification of sources of interference to radio reception. " Catalogue " of characteristics of interfering emissions	Res. 16
VIII/15	United Kingdom	Expeditious method of determining field-strength in the international monitoring system	Q. 253
VIII/16	Portugal	Expeditious method of determining field-strength in the international monitoring system	Q. 253
VIII/17	United Kingdom	Monitoring services in the new and developing countries	Q. 275
VIII/18	Japan	An expeditious method for the determination of field strength in the international monitoring system	Q. 253

Doc.	Origin	Title	Reference
VIII/19	Japan	Automatic monitoring of occupancy of the radio-frequency spectrum. Equipment for the automatic monitoring of occupancy of the radio-frequency spectrum and its performance	Q. 255
VIII/20	Japan	Types and methods of assistance given by monitoring stations to the operation of various radio services	Q. 259
VIII/21	Chairman, Study Group VIII	Interim report by the Chairman, Study Group VIII – International monitoring	
VIII/22	Italy	Proposed revision of Recommendation 182 (Geneva, 1963). Automatic monitoring of occupancy of the radio-frequency spectrum	Rec. 182
VIII/23	Italy	Antennae for monitoring stations	Q. 258
VIII/24	Italy	Proposed revision of Report 277. Measurements at mobile monitoring stations	Rep. 277
VIII/25	U.S.S.R.	Draft opinion on the regulation of out-of-band emissions	Draft Op.
VIII/26	France	Monitoring in new and developing countries	Draft Rep.
VIII/27 (IV/89) and Corr.1	Study Group VIII	Summary Record – Joint opening session	
VIII/28	I.F.R.B.	Proposed modifications to Report 282 – International monitoring facilities	
VIII/29	Study Group VIII	Summary record of the first meeting	
VIII/30	Working Group VIII–A	Monitoring of emissions from spacecraft at fixed monitoring stations	Draft mod. to Rep. 276
VIII/31	Working Group VIII–C	Identification of radio stations (Question 256(VIII))	Draft mod. to Rep. 280
VIII/32	Working Group VIII–A	Accuracy of frequency measurements at monitoring stations (Question 252(VIII))	Draft mod. to Rec. 377
VIII/33	Working Group VIII–A	Frequency measurements at monitoring stations (Question 252(VIII))	Draft mod. to Rep. 272
VIII/34 and Corr.1	Working Group VIII–B	Direction finding at monitoring stations (Question 254(VIII))	Draft Rep.
VIII/35	Working Group VIII–B	Question 258	
VIII/36	Working Group VIII–B	Automatic monitoring of occupancy of the radio-frequency spectrum (Question 255(VIII))	Draft Rec.
VIII/37	Working Group VIII–B	Addition to Report 278	Draft Rep.
VIII/38	Working Group VIII–B	Antennae for monitoring stations (Question 258(VIII))	Draft Rep.
VIII/39	Working Group VIII–A	Method of determining average accuracy of frequency measurements at monitoring stations	Draft S.P.
VIII/40	Working Group VIII–A	Expeditious method of determining field strength at monitoring stations	Draft Q.

Doc.	Origin	Title	Reference
VIII/41	Working Group VIII–A	Expeditious method of determining field strength at monitoring stations (Question 253(VIII))	Draft Rep.
VIII/42	Working Group VIII–A	Measurement of frequencies of single-side band, independent side-band and other complex emissions	Draft Q.
VIII/43	Working Group VIII–A	Expeditious method of determining field strength at monitoring stations	Draft Rec.
VIII/44	Working Group VIII–C	Identification of radio emissions from space-craft	Draft Rep.
VIII/45	Working Group VIII–C	Identification of radio stations (Question 256(VIII))	Draft mod. to Rec. 379
VIII/46	Working Group VIII–A	Measurements at mobile monitoring stations	Draft mod. to Rep. 277
VIII/47	Working Group VIII–A	Proposal to cancel Report 274	Rep. 274
VIII/48	Working Group VIII–A	Draft letter to the Chairman of Study Group I – Bandwidth measurements by monitoring stations	
VIII/49	Working Group VIII–A	Bandwidth measurements by monitoring stations	Draft Rec.
VIII/50	C.C.I.R. Secretariat	List of documents issued (VIII/1 to VIII/50)	
VIII/51	Working Group VIII–A	Bandwidth measurements by monitoring stations	Draft Q.
VIII/52	Working Group VIII–A	Proposed modification to Question 188(VIII)	Q. 188
VIII/53	Working Group VIII–A, B and C	Handbook for monitoring stations	Draft Res.
VIII/54	Working Group VIII–C	Proposed modification to Res. 16. Identification of sources of interference to radio reception	Res. 16
VIII/55	Working Group VIII–B	First report to Study Group VIII	
VIII/56	Working Group VIII–B	Types and methods of assistance by monitoring stations to the operation of various radio services	Draft S.P.
VIII/57	Working Group VIII–B	Types and methods of assistance by monitoring stations to the operation of various radio services	Draft Op.
VIII/58	Working Group VIII–B	Proposed modifications to Report 282. International monitoring facilities	Rep. 282
VIII/59	Working Group VIII–A	Field-strength measurements at monitoring stations	Draft Q.
VIII/60	Working Group VIII–A	Report by W.P. VIII–A to Study Group VIII	
VIII/61	Working Group VIII–B	Types and methods of assistance by monitoring stations to the operation of various radio services	Draft Op.
VIII/62	Working Group VIII–B	Monitoring services in the new and developing countries	Draft Rep.
VIII/63	Study Group VIII	Summary record of the second meeting	

Doc.	Origin	Title	Reference
VIII/64	Working Group VIII–C	Guidance for the I.F.R.B. on the matter of Opinion 11	Op. 11
VIII/65	Working Group VIII–C	Identification of sources of interference to radio-reception	Res. 16
VIII/66	Study Group VIII	Summary record of the third and last meeting	
VIII/67 (IV/166) (VII/57) (IX/159)	C.C.I.R. Secretariat	List of participants – Interim meetings (Monte-Carlo, 1965)	
VIII/68	C.C.I.R. Secretariat	List of documents issued (VIII/51 to VIII/68)	
VIII/69	C.C.I.R. Secretariat	Comments by the Administration of the United Kingdom on Question 291(VIII)	Q. 291
VIII/70	O.I.R.T.	Antennae for radio-monitoring centres	S.P. 182(I)
VIII/71	United States of America	Monitoring of sweeping-type pulse emissions	Q. 226
VIII/72	United States of America	List of stations using sweeping-type pulse emissions	Q. 266
VIII/73	United States of America	Proposed modification to Report 278 – Automatic monitoring of occupancy of the radio-frequency spectrum	Q. 255
VIII/74	United States of America	Measurement of frequencies of single-sideband, independent-sideband and other complex emissions	Q. 295
VIII/75	Japan	Proposed revision of Report 275 – Bandwidth measurement by monitoring stations	Rep. 275, Q. 294
VIII/76	Japan	Bandwidth measurements by monitoring stations	Q. 294
VIII/77	Japan	Bandwidth measurements by monitoring stations	Q. 294
VIII/78	Japan	Measurement of frequencies of single-sideband, independent-sideband and other complex emissions	Q. 295(VIII)
VIII/79	E.B.U.	Exchange of technical information between receiving and measuring stations by means of exchanges of staff	S.P. 259A (VIII)
VIII/80	E.B.U.	Monograph on receiving and measuring stations for broadcasting purposes	Draft Res.
VIII/81	E.B.U.	Measuring methods and apparatus suitable for new and developing countries	Q. 275
VIII/82	I.F.R.B.	Memorandum by the International Frequency Registration Board to C.C.I.R. Study Group VIII concerning a list of stations using special means of identification	Op. 11
VIII/83, Corr.1, and Add.1	Chairman, Study Group VIII	Report by the Chairman, Study Group VIII	
VIII/84	I.F.R.B.	Extension of the international monitoring system to a world-wide scale	Res. 15
VIII/85	I.F.R.B.	Proposed modifications to Report 282 – International monitoring facilities	Rep. 282

Doc.	Origin	Title	Reference
VIII/86	F.S.R. of Yugoslavia	Automatic monitoring of occupancy of a frequency and of operations on that frequency	Rec. 182, Q. 255, Rep. 277
VIII/87	India	Direction finding at monitoring stations	Q. 254
VIII/88	Study Group VIII	Summary record of the first meeting	
VIII/89	Working Group	Proposed modifications to Recommendation 278 – Accuracy of field strength measurements by monitoring stations	Q. 293
VIII/90	Working Group VIII–A	Attention of the Chairman, Study Group I – Equipment for ionospheric sounding	
VIII/91	Working Group VIII–A	Draft Report – Monitoring of sweeping-type pulse emissions	Q. 226
VIII/92	Working Group VIII–A	Draft Question – Measurement of frequencies of single-sideband, independent-sideband and other complex emissions	
VIII/93	Study Group VIII	Draft modification to Report J.f(VIII) – Frequency measurements at monitoring stations	Q. 252
VIII/94	Working Group VIII–A	Draft Report – Measurement of frequencies of single-sideband, independent sideband and other complex emissions	Q. 295
VIII/95	Working Group VIII–A	Draft Recommendation – Bandwidth measurements by monitoring stations	Q. 294
VIII/96	Working Group VIII–C	Draft Report – Identification of sources of interference to radio reception	Q. 257
VIII/97	Working Group VIII–C	Draft Question – Identification of sources of interference to radio reception	
VIII/98	Working Group VIII–A	Draft modification to Report 275 – Bandwidth measurement by monitoring stations	Q. 294
VIII/99	Study Group VIII	Summary record of the second meeting	
VIII/100	C.C.I.R. Secretariat	List of documents issued (VIII/69 to VIII/108)	
VIII/101	Working Group VIII–B	Report by the Chairman	
VIII/102	Working Group VIII–C	Draft Resolution – Handbook for monitoring stations	Q. 257, Q. 275
VIII/103 (I/70)	Study Group I	Draft Report – Approximate methods for the determination of bandwidth	S.P. 180(I), S.P. 181(I)
VIII/104 (I/74)	Study Group I	Letter to the Chairman, Study Group VIII – Bandwidth measurements by monitor-stations	
VII/105 (I/75)	Study Group I	Draft Study Programme – Methods of measuring emitted spectra in actual traffic	
VIII/106	Study Group VIII	Summary record of the third meeting	
VIII/107	Study Group VIII	Summary record of the fourth meeting	
VIII/108	Study Group VIII	Status of texts	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP VIII

Doc.	Title	Final text
VIII/1001	Types and methods of assistance by monitoring stations to the operation of various services	Op. 30
VIII/1002	Identification of radio stations	Rec. 379–1
VIII/1003	Measurement of frequencies of single-sideband, independent-sideband and other complex emissions	Q. 2/VIII
VIII/1004	Accuracy of field-strength measurements by monitoring stations	Rec. 378–1
VIII/1005	Expeditious method of determining field strength at monitoring stations	Rec. 442
VIII/1006	Monitoring of sweeping-type pulse emissions	Q. 7/VIII
VIII/1007	Accuracy of frequency measurements at monitoring stations	Rec. 377–1
VIII/1008	Expeditious method of determining field strength at monitoring stations	Q. 4/VIII
VIII/1009	Monitoring of sweeping-type pulse emissions	Rep. 367
VIII/1010	Expeditious method of determining field strength at monitoring stations	Rep. 368
VIII/1011	Measurements at mobile monitoring stations	Rep. 277–1
VIII/1012	Identification of radio stations	Rep. 280–1
VIII/1013	Monitoring of radio emissions from spacecraft at fixed monitoring stations	Rep. 276–1
VIII/1014	Modification proposed to Report 273	Rep. 273–1
VIII/1015	Bandwidth measurements by monitoring stations	Q. 5/VIII
VIII/1016	Measurement of frequencies of single-sideband, independent-sideband and other complex emissions	Rep. 369
VIII/1017	Types and methods of assistance by monitoring stations to the operation of various radio services – Exchange of technical information between receiving and measuring stations by means of exchanges of staff	Rep. 370
VIII/1018	Bandwidth measurements by monitoring stations	Rep. 275–1
VIII/1019	Frequency measurements at monitoring stations	Rep. 272–1
VIII/1020	Identification of sources of interference to radio reception	Q. 15/VIII
VIII/1021	Handbook for monitoring stations	Res. 16–1
VIII/1022	Automatic monitoring of occupancy of the radio-frequency spectrum	Rec. 182–1
VIII/1023	Bandwidth measurements by monitoring stations	Rec. 443
VIII/1024	Types and methods of assistance by monitoring stations to the operation of various radio services	Op. 29
VIII/1025	Identification of sources of interference to radio reception	Rep. 281-1

Doc.	Title	Final text
VIII/1026	International monitoring facilities – Reply to Recommendation No. 5 of the Administrative Radio Conference, Geneva, 1959	Rep. 282–1
VIII/1027	Monitoring services in the new and developing countries	Rep. 371
VIII/1028	Automatic monitoring of occupancy of the radio-frequency spectrum	Rep. 278–1
VIII/1029	Direction finding at monitoring stations	Rep. 372
VIII/1030	Antennae for monitoring stations	Rep. 373
VIII/1031	List of documents issued (VIII/1001 to VIII/1031)	