INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

XIIth PLENARY ASSEMBLY

NEW DELHI, 1970

VOLUME III

FIXED SERVICE AT FREQUENCIES BELOW ABOUT 30 MHz
(STUDY GROUP 3)
STANDARD FREQUENCIES AND TIME SIGNALS
(STUDY GROUP 7)
VOCABULARY (CIV)

Published by the
INTERNATIONAL TELECOMMUNICATION UNION
GENEVA, 1970

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FIXED SERVICE
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RECOMMENDATIONS AND REPORTS

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STANDARD
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QUESTIONS AND STUDY PROGRAMMES

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

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

1. Recommendations, Reports, Resolutions, Opinions

1.1 *Numbering of these texts*

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

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

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

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(1) Published separately.

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2. Questions and Study Programmes

2.1 *Text numbering*

2.1.1 *Questions*

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

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

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

2.1.2 *Study Programmes*

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

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

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

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

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

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

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

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

2.2 *Arrangement of Questions and Study Programmes*

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

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

(New Delhi, 1970)

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

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

VOLUME III

INDEX*

FIXED SERVICE AT FREQUENCIES BELOW ABOUT 30 MHz

(Study Group 3)

STANDARD FREQUENCIES AND TIME SIGNALS

(Study Group 7)

VOCABULARY

(CIV)

Study Group 3

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

REPORTS

RESOLUTIONS

There are no Resolutions concerning the work of Study Group 3.

Interim Study Group on Vocabulary (CIV)

QUESTIONS AND STUDY PROGRAMMES

There are no Questions and Study Programmes concerning the work of the CIV.

RESOLUTIONS

OPINIONS

There are no Opinions concerning the work of the CIV.

FIXED SERVICE AT FREQUENCIES BELOW ABOUT 30 MHz

STUDY GROUP 3

Terms of reference:

To study questions relating to complete systems for the fixed service 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.

Chairman: S. Aritake (Japan)
Vice-Chairman: N. Chistiakov (U.S.S.R.)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 3

1. Introduction

During the XIIth Plenary Assembly, New Delhi, 1970, certain modifications were made to the terms of reference of Study Group 3. The main modification was the deletion of § 2 in the old terms of reference, concerning the practical application of communication theory. At the same time, the terms of reference of Study Group 1 were entirely revised and new studies for the efficient use of the radio-frequency spectrum were assigned to Study Group 1. Accordingly, the Secretariat of the C.C.I.R. made a tentative transfer of some Questions and Study Programmes from Study Group 3 to Study Group 1 and placed certain Recommendations and Reports in the appropriate section of the printed books.

The texts transferred are shown below with the numbers they bore after the XIth Plenary Assembly, Oslo, 1966.

Recommendations

Recommendation 100	Reduction of occupied bandwidth and transmitter power in radio-telephony
Recommendation 166-1	Unit of quantity of information
Recommendation 341	The concept of transmission loss in studies of radio systems

Reports

Report 112	Transmission loss in studies of radio systems
Report 196-1	Some aspects of the application of communication theory
Report 202	Identification of the carrier-frequency relative to the assigned frequency of an emission
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

Questions and Study Programmes

Question 5/III Communication theory

Study Programme 5A/III Communication theory

Question 9/III Use of common-frequency systems on radiotelephone circuits

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

Question 11/III Automatic control of the output power of the transmitters

Study Programme 19A/III Identification of the carrier frequency relative to the assigned frequency of an emission

It is felt that a somewhat different assignment of the texts would be more appropriate for efficient studies by Study Groups 3 and 1. Therefore, opinions as to the tentative arrangement made by the Secretariat may be expected for the next Interim Meeting. After hearing the opinions of Study Group 3, the Chairmen of the Study Groups concerned will discuss the matter to reach a final decision.

2. Complete systems

2.1 *Antennae*

Concerning antennae for the fixed services, one Recommendation and three Reports constitute the answer to Question 3/3 and Study Programme 3A-1/3.

Recommendation 162-2 Use of directional antennae in the bands 4 to 28 MHz

This Recommendation deals with the practical standard characteristics of directional antennae mostly used for transmission. These characteristics, considered from both technical and economical points of view, are recommended to avoid harmful interference due to unnecessary radiation outside the main beam.

Report 356-1 Use of directional antennae in the bands 4 to 28 MHz

This Report, which was revised during 1966–1969, gives a fundamental method for calculating the directivity of antennae, together with some examples of experimental data measured in relation to Recommendation 162-2.

Report 106-1 Improvement obtainable from the use of directional antennae

This Report also contains various technical data observed in many countries on the directivity of rhombic antennae mostly used for transmission.

Report 107-1 Directivity of antennae at great distances

This Report refers to the directivity of antennae used for reception, including directivity in the vertical plane.

For the period 1970–1973, more data especially on the observed directivity should be invited to support Recommendation 162-2.

2.2 *Bandwidths and signal-to-noise ratios required for the systems of various services*

The bandwidth and the signal-to-noise ratio for a type of service are essential factors in the planning of radio circuits in band 7 (HF) and in designing transmitting equipment, receiving equipment and antennae for the circuits. These factors are also important for international and national allocation of the radiofrequency spectrum in band 7 (HF).

In the four Recommendations described below, summarized values of the data measured and reported by various Administrations are given in reply to Question 1/3.

Recommendation 338-2 Bandwidth required at the output of a telegraph or telephone receiver

This Recommendation deals with the necessary bandwidth at the audio-frequency output of receivers for telegraph and telephone services.

Recommendation 339-2 Bandwidths and signal-to-noise ratios in complete systems

This Recommendation gives the values of signal-to-noise ratios for the various types of service required at the audio-frequency output of receivers and at the radio-frequency stage in relation to the bandwidths at the audio- and intermediate-frequency amplifiers respectively.

Recommendation 240-1 Signal-to-interference protection ratios

This Recommendation shows the minimum protection ratios and frequency separations between a wanted and an interfering signal required for certain teleprinter and facsimile services.

Recommendation 340 Fading allowances for the various classes of emission

While all the values of signal-to-noise and signal-to-interference ratios in the above-mentioned Recommendations are indicated for stable conditions, Recommendation 340 gives total fading allowances for various services and provides the values to correct the ratios for the actual operation with fading not only in the wanted signal but also in the atmospheric noise and interfering signal. Then, the wanted signal strength required at the input of receiver can be calculated, which is essential to the planning and design of radio systems operating in band 7 (HF).

For these Recommendations, more information should be requested from Administrations, especially for Recommendation 240-1, to fill up the vacancies in the Table annexed thereto, and further studies on the values shown in the Tables of Recommendations 339-2 and 340 must be made, because they are still regarded as provisional.

2.3 *Single-sideband, independent-sideband telephone and telegraph systems*

Recently, single-sideband and independent-sideband systems have been widely introduced not only for radiotelephone services but also for multi-channel telegraph services.

For these systems, a new Recommendation has been adopted:

Recommendation 454 Pilot-carrier level for HF single-sideband and independent-sideband reduced-carrier systems

This Recommendation, adopted at the XIIth Plenary Assembly, with a reservation made by one Administration, recommends the application of one standard pilot-carrier level, −20 ±1 dB relative to the transmitter peak envelope power, for all types of transmission with a reduced carrier. This Recommendation sets forth conclusions from studies in connection with Study Programme 1B/3; the technical background for the standard level is introduced in the following Report I:

Report 433 Factors governing the choice of pilot carrier level for independent-sideband radio emissions in band 7 (HF)

Recommendation 349-2 Frequency stability required for single-sideband, independent-sideband and telegraph systems to make the use of automatic frequency control superfluous

This Recommendation gives the permissible frequency error produced in transmitters and receivers for typical services, which enables automatic frequency control devices to be eliminated.

As to single-sideband and independent-sideband systems in general, observations on actual operations would be welcome especially for reviewing the recommended standard level of pilot carrier given in Recommendation 454, taking into consideration the reservation.

2.4 *Miscellaneous*

Report 111 Influence on long-distance HF communications using frequency-shift keying of frequency deviations associated with passage through the ionosphere

This Report, which serves as a partial answer to Question 7/3, refers to the fading and the frequency change due to the drift of ionosphere which may cause errors in telegraph circuits operated by frequency-shift keying.

Report 203 Multipath propagation on HF radio circuits – Measurements of path-time delay differences and their incidence on typical radio links

This Report deals with the values of path-time delay measured on some typical intercontinental circuits operating in band 7 (HF), which may provide important material especially for the study of multipath distortion in radiotelegraph systems. More contributions are invited from Administrations for the values of delay observed on various actual radio circuits, considering the significant effect of multipath on radiotelegraph systems, as stated in Report 345-1. These contributions are also helpful for the studies of the new Question 21/3 (Ionospheric channel simulators).

Report 109-1 Radio systems employing ionospheric scatter propagation

This text contains sufficient technical information on ionospheric-scatter systems.

Report 357 Operational ionospheric sounding at oblique incidence

Here, general techniques for applying ionospheric sounding to practical operation on radio circuits operating in band 7 (HF) are explained, although ionospheric-scatter systems and ionospheric-sounding techniques are not widely used at present.

Recommendation 337-1 Channel separation

This Recommendation deals with general considerations for frequency separation between radio channels. Recommendation 337-1 could appropriately be transferred to Study Group 1, because this Recommendation could apply to all types of radio service.

3. **Radiotelephony**

3.1 *Improved transmission system*

During the period 1966–1969, studies, in connection with Question 13/3, had been made to introduce an improved transmission system with new radiotelephone terminal equipment. Consequently, the following Recommendation was adopted unanimously by the XIIth Plenary Assembly (New Delhi):

Recommendation 455 Improved transmission system for HF radiotelephone circuits.

The main principle of the new system is to link the action of a compressor at the transmitting end with that of an expander at the receiving end by using a control tone, which enables the power of radio transmitter to be used to the fullest extent at all times independently of the level of speech. The Recommendation describes the standard characteristics of new radiotelephone terminal equipment which should be used for the improved system.

The system with new equipment (sometimes called LINCOMPEX, an abbreviation for "Linked Compressor and Expander") can provide a radiotelephone circuit of superior quality to that operated with conventional equipment, as described in the following Report 354-1, which summarizes the observed data obtained through tests and actual services in several countries.

Report 354-1 An improved transmission system for use over HF radiotelephone circuits.

For some time, many Administrations have been planning to use the new equipment to improve radiotelephone circuits. Therefore, any information as to the technical precautions to be taken on introducing the new system would be welcome, especially contributions from Administrations which have already put it into practical service.

3.2 *Miscellaneous*

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

This Recommendation shows the standard arrangement of telephone channels for single-sideband and independent-sideband transmission. Opinions are invited as to whether the arrangement shown in Fig. 2 of this Recommendation should still be maintained.

Recommendation 335-2 Use of radio links in international telephone circuits

This Recommendation gives general principles for radiotelephone circuits.

Recommendation 336-2 Principles of the devices used to achieve privacy in radiotelephone conversations

This Recommendation describes the standards of privacy devices. In this regard, the necessity of maintaining the use of band-splitting systems as standard could be discussed, taking account of the introduction of systems using linked compressor and expander and the complexity of the privacy device.

Report 353 Use of common-frequency systems on international radiotelephone circuits

This Report deals with technical arrangements for operating a radiotelephone circuit at a common radio frequency at both transmitting and receiving ends in answer to Question 19/1, which was transferred to Study Group 1. This arrangement may be helpful in solving the problem of the shortage of radio-frequency spectrum in band 7 (HF) for radiotelephone services.

Report 355-1 Use of diversity on international HF radiotelephone circuits

This Report shows, in connection with Question 13/3, three diversity techniques useful for improving the quality of radiotelephone services in band 7 (HF).

Report 434 Transmission characteristics of HF radiotelephone circuits

This Report is a partial answer to Question 16/3. It introduces an arrangement being used by the French Administration for operating radiotelephone circuits in band 7 (HF) connected to semi-automatic exchanges, when the circuit is under stable conditions. In connection with Question 16/3, the feasibility of operating radiotelephone circuits in band 7 (HF) with the linked compressor-expander technique in an automatic telephone network could be studied.

4. Radiotelegraphy and facsimile

4.1 *Frequency-shift keying*

Recommendation 246-2 Frequency-shift keying

This Recommendation, which was revised during the period 1966–1969, gives standard values of frequency shift and the correspondence between, on the one hand, the higher and lower frequencies and, on the other hand, the significant conditions of modulation for various international standard signals with regard to Question 8/3.

Recommendation 346-1 Four-frequency diplex systems

This Recommendation deals with the standard arrangement of two telegraph channel systems using frequency-shift keying with four equally-spaced frequencies. This system is sometimes called "Twinplex" or "Diplex". Study Programme 8A/III was terminated because studies on four-frequency diplex systems were completed.

4.2 *Voice-frequency telegraphy*

As a result of development of techniques for single-sideband transmission, nowadays multi-channel voice-frequency telegraph systems are widely used in many countries. Therefore, the studies of this system were carried out in many respects according to Questions 1/3, 2/3 and Study Programme 17A-1/3. The studies are summarized in the following Recommendations and Reports.

Recommendation 106-1 Voice-frequency telegraphy on radio circuits

This Recommendation describes the diversity techniques essential for the voice-frequency telegraph systems.

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

This Recommendation deals with the designations of sub-carriers, multiplex systems on the sub-carriers, time-division channels and sub-channels, to achieve uniformity and to avoid possible confusion in the arrangement and operation of complex multi-channel systems using voice-frequency telegraphy.

Recommendation 436-1 Arrangement of voice-frequency telegraph channels working at a modulation rate of about 100 bauds over HF radio circuits

Two types of channel arrangement for the international standard are given in this Recommendation. It should be noted that for radio circuits in band 7 (HF), an arrangement differing from the standard widely used for circuits other than for radio systems in band 7 (HF) is recommended in which sub-carriers, separated by 170 Hz and starting from 425 Hz, should be applied as shown in Table I of this Recommendation. The first type is a frequency-shift system for channels with a modulation rate of approximately 100 bauds employing 2-channel ARQ on each sub-carrier. The second is a frequency-exchange system, a typical arrangement of which is to use two sub-carriers separated by 340 Hz for the same modulation rate. The first type is usually preferred for actual services, for the reasons mentioned in Report 345-1.

The studies which were made to prepare the above Recommendations are described in several Reports as follows:

Report 19-1 Voice-frequency telegraphy over HF radio circuits

This Report deals with the general technical considerations which should be taken into consideration when using voice-frequency telegraph systems over radio circuits operating in band 7 (HF).

Report 42-2 Use of radio circuits in association with 50-baud 5-unit start-stop telegraph systems

This Report describes the superiority of synchronous systems in radiotelegraph circuits operating in band 7 (HF) as compared with start-stop telegraphy and also introduces the possibility of an arrangement of voice-frequency telegraphy, with a channel spacing of 120 Hz, differing from the arrangement given in Recommendation 436-1.

Report 347 Voice-frequency telegraphy over radio circuits

Some information on the actual operation of the arrangement described in Report 42-2 is given here.

Report 198 Voice-frequency (carrier) telegraphy on radio circuits

This short Report gives two different values for the optimum frequency shift as a function of the modulation rate. However, as Recommendation 436-1 has already been adopted, cancellation of this Report could be considered.

Report 345-1 Performance of telegraph systems on HF radio circuits

This is the main Report containing important material on the basis of which Recommendation 436-1 was prepared. The material covers the results of theoretical studies, laboratory tests using fading simulators and tests on actual radio circuits conducted by many Administrations, comparing typical systems of voice-frequency telegraphy.

In this Report, typical systems are classified: System A, frequency-exchange systems (the second type in Recommendation 436-1), and System B, frequency-shift systems. System B is divided into B1, corresponding to the first type in Recommendation 436-1, and B2, with a channel spacing of 340 Hz and frequency shift of 170 Hz for each sub-carrier operating at modulation rates up to 200 bauds.

As a result of extensive studies, it is reported that the order of merit for these three systems, operated with ARQs of 2 or 4 channels, was A, B1, then B2. Although System A was superior to System B1, especially under poor propagation conditions, System B1 could usually be considered preferable because it has twice the channel capacity as compared with System A. Moreover, it was recognized that not only the signal-to-noise ratio but also signals due to multipath propagation would be important factors affecting the quality of transmission, particularly in System B which uses a narrow-frequency shift.

Furthermore, in connection with Question 12/3, there is a Recommendation and a Report concerning high-speed data transmission using the arrangement of voice-frequency telegraph systems.

Recommendation 456 Data transmission at 1200/600 bits/s over HF circuits when using multi-channel voice-frequency telegraph systems and frequency-shift keying

This new Recommendation describes a standard system for data transmission operated with the arrangement of voice-frequency telegraph systems with frequency-shift, described in Recommendation 436-1.

Different types of system using phase-shift keying on voice-frequency sub-carriers, which would be applicable rather to high-speed data transmission, are described in the following Report, together with the results of tests made on radio circuits operating in band 7 (HF).

Report 346 Performance of systems using phase-shift keying over HF radio circuits

Considering the possibility of transmission of more digital information, such as data transmission at higher speeds, further studies should be made as to the practicability of multi-phase, phase-shift systems on radio circuits operating in band 7 (HF).

4.3 *Automatic error-correcting systems*

These systems are dealt with in one Recommendation and four Reports.

Recommendation 342-2 Automatic error-correcting system for telegraph signals transmitted over radio circuits

This Recommendation, which was slightly amended at New Delhi, deals with the standard characteristics of an automatic error-correcting system with 4-channel or 2-channel time-division multiplex which has been widely used for telegraph service on radio circuits in band 7 (HF), using the 7-unit International Telegraph Alphabet No. 3. Especially, when telex services, in accordance with C.C.I.T.T. Recommendations, are to be provided on radio circuits in band 7 (HF), this system is essential, not only for protection against errors, but also for provision of the signalling required for the service. Since this Recommendation has been studied thoroughly, no further study is deemed necessary.

On the other hand, three of the four Reports refer to many single-channel systems.

Report 348-1 Single-channel simplex ARQ telegraph system

This Report introduces an automatic error-correcting system for single-channel telegraph circuits, in which alternate operation is provided over the radio link. In this system, almost the same principle as that described in Recommendation 342-2 is utilized for error correction, although a 7-unit code different from International Telegraph Alphabet No. 3 is used. To keep the speed of communication in simplex mode as high as possible, signals are transmitted block by block, each block consisting of three characters, at a modulation rate of 100 bauds. Considering that Recommendation 476, entitled "Direct printing telegraph equipment in the maritime mobile service", which recommends an automatic error-correcting system of almost the same principle, was adopted by the XIIth Plenary Assembly, New Delhi, opinion should be invited as to the possibility of recommending the system described in Report 348-1 as an international standard for the fixed service.

Report 350 Single-channel duplex ARQ telegraph system

This Report introduces yet another system for single-channel telegraphy which applies the same principles as those given in Recommendation 342-2.

Report 349-1 Single-channel radiotelegraph systems employing forward error correction

In this Report, the test results obtained both on real circuits and in laboratories using fading simulators, are summarized for various types of forward error-correcting systems, in which errors can be corrected at the receiving end without a return circuit to the transmitting end. This type of system may be used for telegraph services of a broadcasting type, therefore further studies and discussion are required on the need for standardizing the characteristics for such types of automatic error-correcting systems.

Report 435 Error statistics and error control in digital transmission over operating radio circuits

A summary of studies mostly concerning the various kinds of code suitable for error control is described. These studies could be considered appropriate to Study Group 1 for communication theory, because this Report is a partial answer to Study Programme 18A/1.

Report 436 Efficient use of HF radiotelegraph channels in the telex network by means of automatic selection and allocation procedures

Besides the four Reports described above, a system called "Flex" is introduced in this Report. The "Flex" is planned to operate telex channels more efficiently, when many ARQ channels for telex services are operated to a single destination, for instance, using voice frequency telegraphy.

4.4 *Quality of performance*

Recommendation 345 Telegraph distortion

This Recommendation introduces definitions of various types of telegraph distortion and error-rate, which appear in the List of Definitions published by the I.T.U.

Report 200-1 Telegraph distortion, error-rate

This Report briefly summarizes studies of distortion and error-rate carried out by the C.C.I.T.T. and the C.C.I.R.

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

This Report deals mostly with basic studies for the prediction of performance of a telegraph circuit in connection with the receiving system. These studies could be useful for evaluating the effect of diversity systems and the signal-to-noise ratio required for a telegraph circuit.

Report 197-2 Factors affecting the quality of performance of complete systems in the fixed service

This Report summarizes several contributions concerning the tendency to variation of telegraphic distortion and error-rate in various kinds of radio circuits operating in band 7 (HF). This Report may be used to predict the quality of the circuit.

Report 437 Operational use of efficiency factor

This is a new Report, in which abstracts from two contributions concerning the use of efficiency factor as a measure of evaluating and predicting the performance of an ARQ circuit are introduced. This Report could be a partial answer to Study Programme 1C/3, especially as regards operating ARQ circuits on fully automatic telex networks.

Report 351-1 Quality of performance of radiotelegraph systems

The results of observations on efficiency factor and distortion of several radiotelegraph circuits are introduced in this Report. It is reported that measurement of distortion could provide a more convenient and direct means for measuring the efficiency factor, although the efficiency factor can give the grade of quality of the total system in both directions. Some apparatus used for the measurement of distortion is also described in this Report.

4.5 *Facsimile*

There are two Recommendations and two Reports concerning facsimile, including phototelegraph transmission.

Recommendation 344-2 Standardization of phototelegraph systems for use on combined radio and metallic circuits

This Recommendation, which was slightly amended at the XIIth Plenary Assembly, gives international standards for phototelegraph transmission and its associated apparatus. In this Recommendation, the views of Administrations are invited as to the need for maintaining the characteristics of apparatus shown as type "b" in § 2, in which an index of cooperation of 264 and drum speed of 90/45 r.p.m. are given.

Recommendation 343-1 Facsimile transmission of meteorological charts over radio circuits

The standard characteristics for transmission of meteorological charts are described in this Recommendation.

Report 201-2 Remote control signals for facsimile transmissions

This Report deals with the C.C.I.T.T. Recommendation and proposals for the remote control signals for facsimile both for the meteorological and for the subscribers' services.

Report 352 Use of pre-emphasis and de-emphasis for phototelegraph transmission over HF radio circuits

This Report introduces a new technique to use pre-emphasis and de-emphasis, by which the quality of picture received may be improved.

5. Handbook

Considering the decision made in Resolution 33-1, the preparation of a special handbook for "planning, maintenance and operation of the fixed service in band 7 (HF)" should be carried out, especially for new or developing countries. Although the handbook should deal with the transmitter, receiver, and ionospheric propagation which are studied by Study Groups 1 and 6, Study Group 3 would be responsible for preparing the handbook as a whole.

Therefore, during the period 1970–1973, the preparation should be promoted by, for instance, forming an Interim Working Party to meet the urgent needs of new or developing countries. Considering the purpose of the handbook, the first edition could be practical and simple, avoiding theoretical explanations and possible delay in issuing it. It could also be desirable to finish the preparation of the first edition, even partially, before the XIIIth Plenary Assembly, in a form similar to the Handbook for Monitoring Stations.

6. New Question

Considering the important role of channel simulators for studies of radiocommunication in band 7 (HF), used in laboratories mostly for the testing of digital transmissions, a new Question was established:

Question 21/3 HF ionospheric channel simulators

Any contribution giving data to answer, even partially, this Question would be welcome, i.e. concerning the various types of fading, the patterns of multi-signal due to multipath, and other factors which should be simulated in the channel simulator. On the other hand, it should be noted that complex simulations should be avoided, to make the simulator as simple as possible.

SECTION 3A: COMPLETE SYSTEMS

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 162-2

USE OF DIRECTIONAL ANTENNAE IN THE BANDS 4 TO 28 MHz

(Question 20/1)*

The C.C.I.R., (1953 – 1956 – 1966 – 1970)

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 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 20/1, 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 techniques;

UNANIMOUSLY RECOMMENDS

1. Definitions

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

1.1 *Directive gain* (G_0)**

In a given direction, 4 π times the ratio of the intensity of radiation***, in that direction, to the total power radiated by the antenna.

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* This Question replaces Question 10/III.

** See No. 99 of the Radio Regulations for a definition of power gain.

*** The intensity of radiation is the power per unit solid angle (steradian).

Note. — The attention of the Interim Study Group on Vocabulary (CIV) is drawn to this new definition of directive gain, and it is asked to say whether this is in accordance with the definitions proposed by other international organizations, e.g. the IEC.

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 directivity factor, M, of the antenna used should be equal to or greater 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 directivity factor, M, of the receiving antenna should be equal to or greater 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 356-1.

Explanatory notes

The values of directive gain and service sector appropriate to the specified values of M 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_0(dB)	$S°$	M	G_0(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_0. 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.

Furthermore, when calculated gains, based on constant-current formulae, are used to determine the M-factor, adjustment should be made to allow for the current decay along the actual antenna. Methods of making these adjustments are described in Report 356-1.

No preferred polarization or type of antenna is established. Horizontal polarization offers better ground 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 randomization 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.

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RECOMMENDATION 240-1

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS

(Question 1/3, Study Programme 1A-1/3)

The C.C.I.R., (1953 – 1956 – 1959 – 1970)

CONSIDERING

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

UNANIMOUSLY 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.

Table

Minimum protection ratios and frequency separations required under stable conditions

Table (cont.)

Wanted signal		Interfering signal																																			
Type of service		A1 50 bauds(1)				A1 100 bauds				F1-50 bauds $2D = 280$ Hz(1)				F1-50 bauds $2D = 400$ Hz(1)				F1-100 bauds $2D = 400$ Hz				F6-50 bauds $2D = 1200$ Hz				A3(6)				A3A(7)				A3J(8)				Broadcast(5)			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	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)			(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(3) $2D = 280$ Hz, $B = 3000$ Hz														3	0·43	0·6	1·48					3	0·95	1·16	2·25		0·6	1·0	5·0		<1·5	1·5	2·3		<1·5	1·5	2·1	(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				15	1·10	1·20																					
F6 (3) 50 baud teleprinter $2D = 1200$ Hz $B = 1200$ Hz	Channel 1													8	0·85	0·95	1·51					8	1·24	1·33	2·32																
	Channel 2													18	0·98	1·1	2·06					18	1·33	1·51	3·08																

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 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 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 1/10 000.
(3) For a character error rate of 1/1000.
(4) For a traffic efficiency of 90%.
(5) Average degree of modulation 40%; for this test the sideband components extended to ± 9 kHz.
(6) Average degree of modulation 70%; sideband components extended to ± 3 kHz.
(7) Carrier 20 dB below sideband amplitude; bandwidth limited to 3 kHz.
(8) Bandwidth limited to 3 kHz.

RECOMMENDATION 337-1

CHANNEL SEPARATION

The C.C.I.R., (1948 – 1951 – 1953 – 1963 – 1970)

CONSIDERING

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

- the signal power and spectral distribution required by the receiver;
- the power and spectral distribution of the interfering signals and noise intercepted by the receiver;

(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;

UNANIMOUSLY RECOMMENDS

1. that the required separation between channels should be calculated by the following method:

- determine the power and spectral distribution of the signal intercepted by the receiver;
- determine the power and spectral distribution of the interfering signals and noise intercepted by the receiver;
- determine, from these data, the degree of frequency separation that will provide the required grade of service and the required service probability. 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.

Note. — Reports 322, 413, 414 and 415 may be found useful in this connection.

RECOMMENDATION 338-2

BANDWIDTH REQUIRED AT THE OUTPUT OF A TELEGRAPH OR TELEPHONE RECEIVER

(Question 1/3)

The C.C.I.R., (1953 – 1963 – 1966 – 1970)

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 class of emission A1, the bandwidth in hertz, after the final detector stage, should be equal to 2·5 times the modulation rate in bauds;

1.2 for class of emission F1, 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 335-2, the upper limit frequency should be reduced to 3000 Hz or less but no lower than 2600 Hz. In the case of the improved radio telephone system using a linked compressor-expander (Recommendation 455), the bandwidth should be strictly preserved to not less than 3000 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 339-2

BANDWIDTHS AND SIGNAL-TO-NOISE RATIOS IN COMPLETE SYSTEMS

(Question 1/3)

The C.C.I.R., (1951 – 1953 – 1956 – 1963 – 1966 – 1970)

CONSIDERING

that it is not yet possible to give a full and accurate answer to Question 1/3, but to assist in giving such an answer, it is desirable to classify the important points with which future studies 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 Table I be extended to include additional systems as the pertinent information becomes available;

3. 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.

Note. — In these studies, the procedures given in Reports 195, 413, 414 and 415 should be given full consideration.

TABLE I

Signal-to-noise ratios required

(Stable conditions)

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, commercial grade	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
24 baud, commercial grade	1·5	11	3	12
F1 frequency-shift telegraphy				
120 baud, recorder	0·25	4	1·5	2
50 baud, printer	0·10	10	1·5	− 2
F3 telephony (3) *D* is the frequency deviation (kHz) *M* is the audio bandwidth (kHz) *K* is normally 1, but sometimes a higher value is necessary (Above the FM threshold, the ratio of peak radio-frequency signal-to-noise in a 6 kHz band, is lower by $(10{\cdot}8+20 \log D/M)$ dB than that required for A3 double-sideband telephony)	3		$2M+2DK$	
F4 phototelegraphy				
Sub-carrier frequency-modulation single-sideband emission	3	15	3	12
Hellschreiber				
Frequency-shift	1·5	6	3	3
Telephony		(Note 2)		(Note 5)
Double-sideband, just usable quality, operator to operator (Note 3)	3	6	6	18
Double-sideband, marginally commercial (Note 4)	3	15	6	27
Double-sideband, good commercial quality (Note 4)	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 4)				
1 channel	3	15	3	18
4 channels	3	15	3(2)	20 (1), (4)
Good commercial quality (Note 4)				
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 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. — For telephony, the figures in this column represent the ratio of the audio-frequency 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 3. — For 90% intelligibility of unrelated words.

Note 4. — When connected to the public service network.

Note 5. — The values of the radio-frequency signal-to-noise ratio for telephony listed in this column, apply when conventional terminals are used. They can be reduced considerably (by amounts as yet undetermined) when terminals of the type using linked compressor-expanders are used (see Report 354-1). A speech-to-noise (r.m.s. voltage) ratio of 7 dB measured at audio-frequency in a 3 kHz band has been found to correspond to just marginally commercial quality at the output of the system, taking into account the compandor improvement.

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 1/3, Study Programme 1A-1/3)

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

CONSIDERING

(a) that Table I to Recommendation 339-2 is a provisional and partial reply to Question 1/3, 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-1/3;

(d) that, however, the information contained in Reports 248-2 and 266-2 give some results from which provisional data on fading allowances can be derived;

UNANIMOUSLY RECOMMENDS

1. that the studies in connection with Recommendation 339-2 and Study Programme 1A-1/3 should be continued, in conjunction with those of Study Programme 16A-1/6 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 339-2, 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.

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

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(1) Combined fading safety factor and intensity fluctuation allowances.
(2) From Recommendation 339-2, 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 (United States of America), 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 349-2

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

The C.C.I.R., (1963 – 1966 – 1970)

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, 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 (1) of Table I are decisive for the system, and that those given in the columns (2), (3) and (4) 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 and telephone systems using the principle of constant overall transmission loss, as set forth in Recommendation 455, 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 340 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 ≈ 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 344-2. 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 454*

PILOT CARRIER LEVEL FOR HF SINGLE-SIDEBAND AND INDEPENDENT-SIDEBAND REDUCED-CARRIER SYSTEMS

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

CONSIDERING

(a) that independent-sideband reduced-carrier systems often operate with reduced pilot carrier levels of –26 dB relative to transmitter peak envelope power;

(b) that although for conventional radiotelephone systems a level of –26 dB appears, theoretically, to be adequate, operational experience shows that significant improvements in operational time are secured with higher levels;

(c) that, for radiotelephone systems employing a frequency-modulated control channel, further protection of the pilot carrier is necessary to ensure end-to-end circuit gain stability;

(d) that on currently operated multi-channel radiotelegraph systems a level of –26 dB is, both theoretically and in operational experience, inadequate to ensure reliable action of the automatic frequency control system down to the failure point of the telegraph channels;

(e) that the levels of reduced-carrier in use by various Administrations range from –16 to –26 dB relative to peak envelope power;

(f) that a standard level of reduced pilot carrier for all single-sideband and independent-sideband emissions would be operationally advantageous;

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* The Administration of Pakistan reserved its opinion on this Recommendation.

(g) that the linearity of modern transmitters is much improved over that of transmitters which were in use at the time independent-sideband working was introduced;

RECOMMENDS

1. that a standard pilot-carrier level of −20 dB ± 1 dB relative to transmitter peak envelope power be adopted for all fixed service single-sideband and independent-sideband reduced-carrier HF radio emissions;

2. that Administrations should make appropriate bilateral arrangements to introduce the new level as soon as is operationally convenient.

3A: *Reports*

REPORT 106-1*

IMPROVEMENT OBTAINABLE FROM THE USE OF DIRECTIONAL ANTENNAE

(Question 3/3)

(1953 - 1956 - 1959 - 1970)

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 Docs. 19, 139, 265, 320 and 532, Warsaw, 1956, which also refer to this Question. The relation of these preliminary results to the median gain, given by Recommendation 162-2, is indicated.

In the text below:

l = length of leg (m),
φ = half the obtuse angle (degrees),
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, φ = 75°. This first set of measurements was made relative to a *vertical antenna*; the results are otherwise expressed in Recommendation 162-2.

TABLE I

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		Half of main arc	Arc $A_1 = A_2$	Half of arc B
			Unidirectional antenna	Reversible antenna			
10	0	-8	-21	-12	23	22	135
15	0	-6		-17	18	29	133
20	0	-8	-23	-15	13	24	143

In 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 omnidirectional 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

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* This Report was adopted unanimously.

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		15·2	11·7	7·7
29 Sept. - 11 Oct. 1956	217		12·9	10·7	6·8
28 Feb. - 23 Mar. 1957	405		10·8	7·1	0·0
15 - 25 January 1958	162		11·1	8·5	3·2
Receiving PPZ 18 MHz					
29 Sept. - 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 at 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 (Geneva, 1963), as follows:

TABLE III*a*

Frequency	Median value(¹) of gain relative to half-wave dipole (dB)			Azimuthal range (degrees) (Rec. 162)		
	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 MHz (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 (Geneva, 1963); 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. 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 (degrees) . . .	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 (Geneva, 1963).

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 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-1/3 may 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-1/3) to specify the directivity of antennae at both terminals.

REPORT 107-1*

DIRECTIVITY OF ANTENNAE AT GREAT DISTANCES

(Question 3/3)

(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.

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* 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 3/3—Directivity of antennae at great distances.
- Study Programme 3A-1/3—Improvement obtainable from the use of directional antennae
- Recommendation 162-2—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 and July, 1961	4900	2°	9°	13·5°
Poona(¹) (India)	7300	14·5	April, June and July, 1961	4434	3°	9°	13°
Sydney(¹) (Australia)	17000	14·7	June and July, 1961	3780	4°	9°	13°
Barbados	6800	7·5	August, 1963	2954	2°	4°	7°
			November, 1963	798	3°	6°	8°
			January, 1964	437	3°	7°	10°

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

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* 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 4/3)

(1959 - 1966)

A contribution, relating to Question 4/3, has been received from the United States of America (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 260-2.

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* 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 260-2 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 single-sideband, or narrowband 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 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 times 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 in arctic regions.

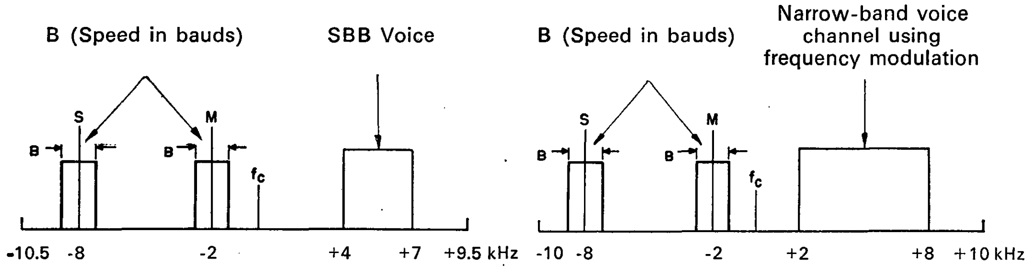

FIGURE 1

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 7/3)

(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

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* This Report was adopted by correspondence without reservation.

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

Fig. 1 shows the cumulative probability distribution of the instantaneous frequency. This curve has been 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 for 99·96% of the time.

Taking into account the fading rate indicated in Report 266-2, 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. Conclusion

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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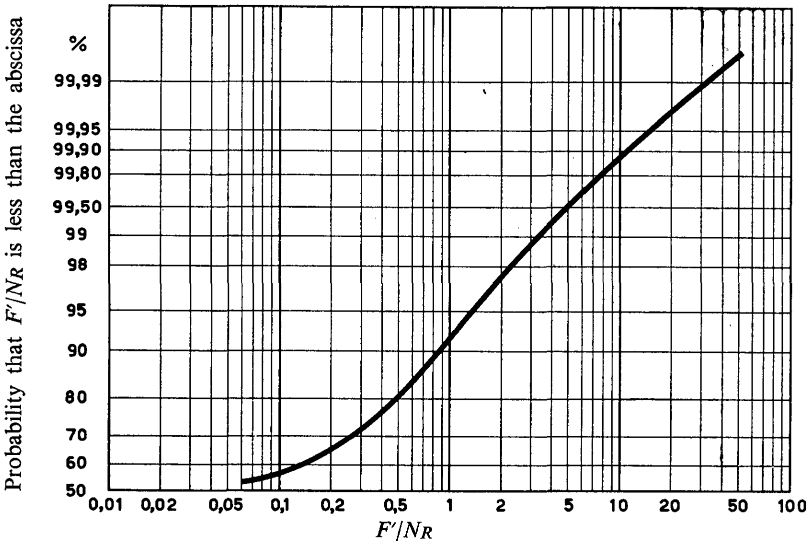

FIGURE 1

Cumulative probability distribution of instantaneous frequency change

F' = Instantaneous departure from centre frequency (Hz)

N_R = Fading rate (fades per second)

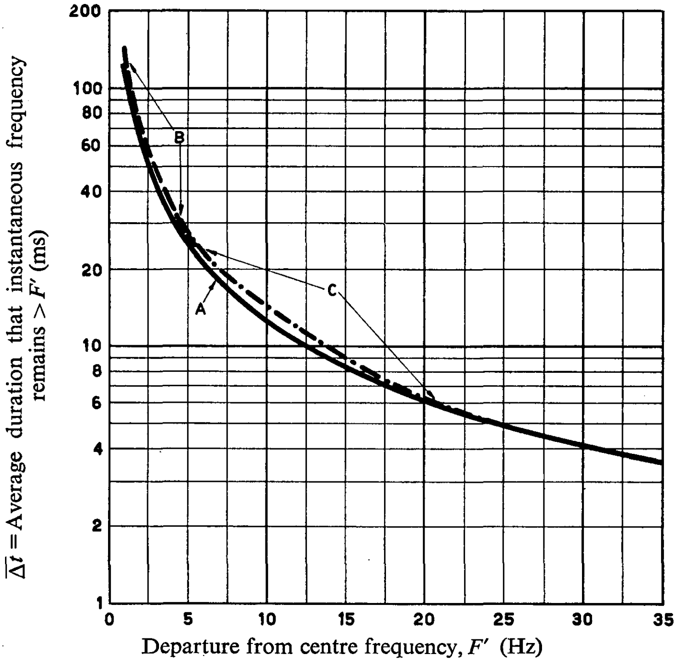

FIGURE 2

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)

Curve A: 0·2 fade /second

Curve B: 1 fade/second

Curve C: 5 fades/second

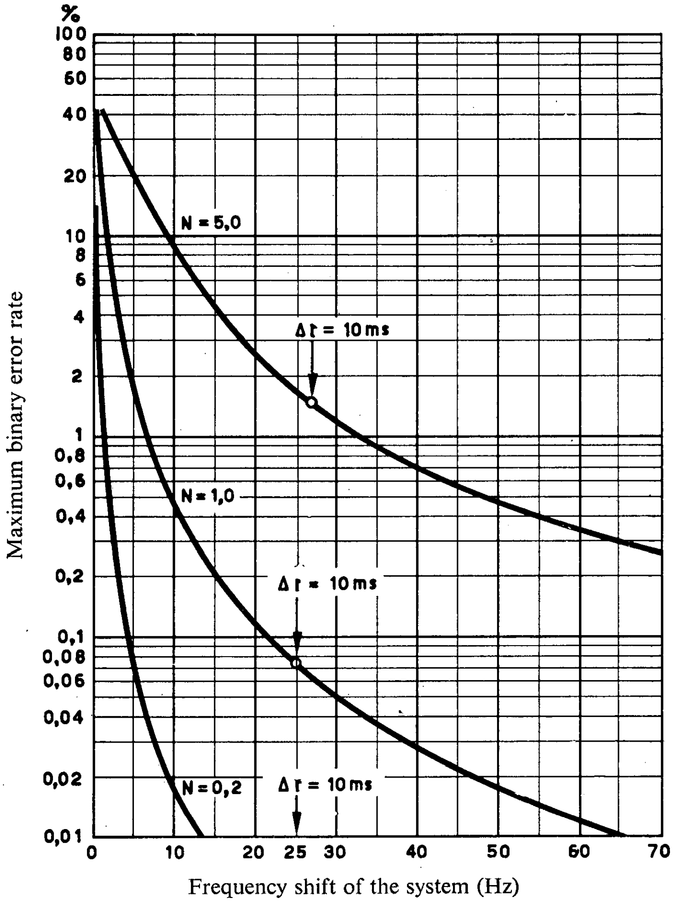

FIGURE 3

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

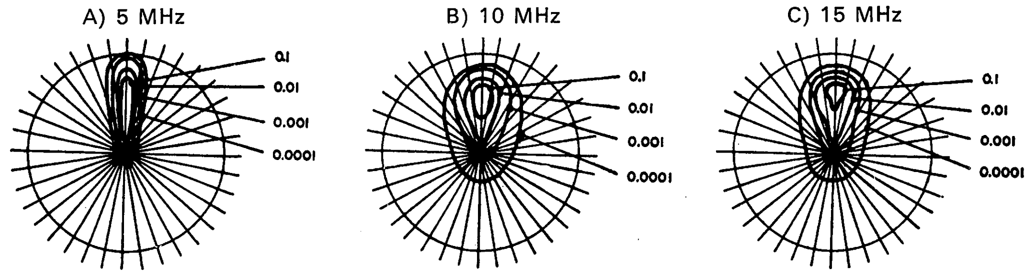

FIGURE 4

Polar probability contours of phase change and amplitude of WWV

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

REPORT 203*

MULTIPATH PROPAGATION ON HF RADIO CIRCUITS

Measurement of path-time delay differences and their incidence on typical radio links

(Study Programme 1A-1/3)

(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 take place 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 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.

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* This Report was adopted unanimously.

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, rare, 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 differences of 1 ms or more, and nearly 30% had delay differences of 1·5 ms or more.

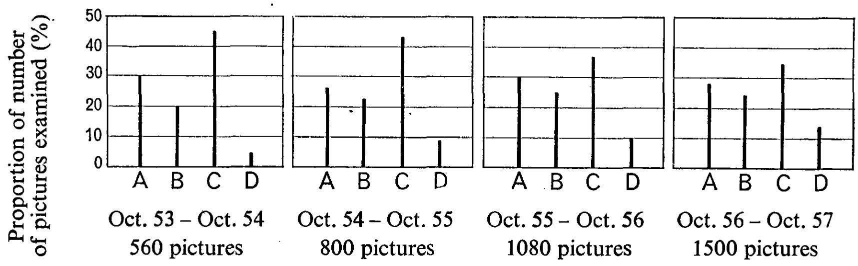
Multipath effects such as these are not particularly troublesome in facsimile transmission. Facsimile pictures have been used merely as a convenient means of obtaining data on incidence and delay difference over a long period on typical high-frequency fixed-service radio links. The effect of such multipath 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

§ 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 transmission from Washington, D.C., and from Japan.

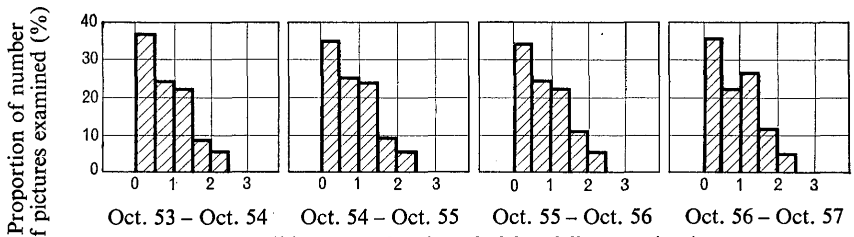
Some 1600 charts received during the period June to September, 1961, have been analyzed. Of these, 1000 were received from Washington and 600 from Japan. The method of measuring the path-time delay differences was similar to that described in § 1 of this Report. The results are tabulated below and are 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

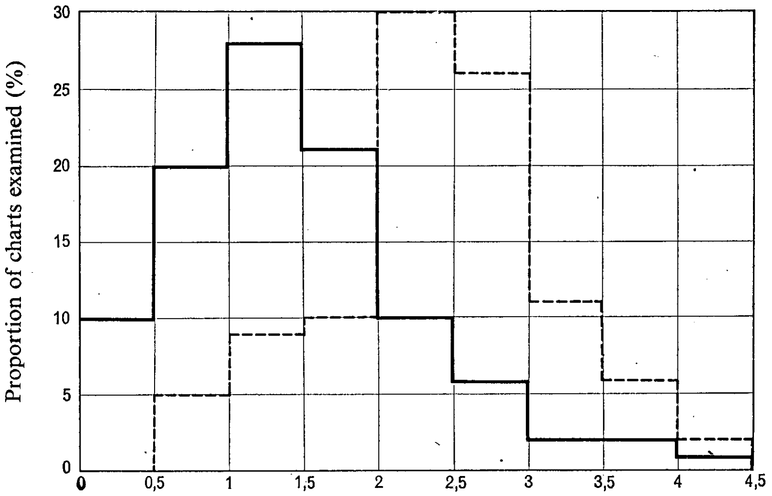


FIGURE 2

Multipath propagation on circuits of the meteorological broadcast service

——— Washington, D.C. to United Kingdom

------- Japan to United Kingdom.

REPORT 356-1*

USE OF DIRECTIONAL ANTENNAE IN THE BAND 4 TO 28 MHz

(Recommendation 162-2)

(1966 – 1970)

1. Introduction

Question 20/1 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 modifications, 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

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* This Report was adopted unanimously.

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:

$$G = P_0/P = 32\pi^2/(\pi^2-4)\ \theta_0\varphi_0 = K/\theta_0\varphi_0 \tag{1}$$

(θ_0 and φ_0 are the horizontal and vertical angular widths respectively, in radians and P, P_0 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_0', φ_0', then from (1), the power radiated in the main beam:

$$P' = P_0\theta_0'\ \varphi_0'/K \tag{2}$$

If this represents a fraction q of the total radiated power,

$$G' = q\,.\,P_0/P' = qK/\theta_0'\varphi_0' \tag{3}$$

$$\text{or}\ \ q = G'\theta_0'\varphi_0'/K \tag{4}$$

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:

$$P_0\,(1-q)/G'$$

If this were distributed evenly over the residual hemisphere outside the lunar arc θ_0' the average power flux would be

$$P_0\,(1-q)/(2\pi-\theta_0')\ G'$$

Since the maximum flux in the main beam is $P_0/4\pi$, we can write

$$\frac{\text{Maximum useful signal power flux}}{\text{Average interfering signal power flux}} = \frac{G'(2\pi-\theta_0')}{(1-q)\,4\pi} \tag{5}$$

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 assumed for the main beam is used then, for the secondary beams:

$$\left(\frac{F\,\text{max}}{F\,\text{average}}\right)^2 = \frac{2\pi^2}{\pi^2-4} = 3\cdot41\ (5\cdot3\ \text{dB})$$

and we can then write,

$$\frac{\text{Maximum useful signal power flux}}{\text{Maximum interfering signal power flux}} = \frac{G'\,(2\pi-\theta_0')}{(1-q)\,4\pi \times 3\cdot41} \tag{6}$$

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,

$$M = \frac{G'\,(2\pi-\theta_0')}{(1-q)\,4\pi \times 3\cdot41}\cdot\frac{10}{\Delta_m}$$

and expressing θ_0', φ_0' in degrees,

$$M = \frac{G'\,(360-\theta_0')}{245{\cdot}6\,\Delta_m(1-q)} \tag{7}$$

$$\text{where}\quad q = \frac{G'\theta_0'\,\varphi_0'}{176\,600}$$

G' = directive gain of antenna expressed relative to an isotropic radiator (expressed as a ratio unless otherwise stated),

θ_0' = horizontal angular width of main beam in degrees (to first minimum points),

φ_0' = vertical angular width of main beam in degrees (to first minimum points),

Δ_m = vertical angle of main beam maximum (degrees).

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.

3. Determination of directive gain

When the measured characteristics of antennae are available, particularly the (power) gain and angular beamwidths, calculation of the figure of merit, M, is straightforward provided the power efficiency of the antenna is known. In many instances, however, it will be necessary to evaluate paper designs and special care is needed in the case of the rhombic antenna. Although the angular dimensions of the main beam and the vertical angle of the main beam maximum can be predicted with sufficient accuracy by a calculation which assumes constant current in the antenna wires [1] the gain so calculated is generally optimistic and must be corrected before it can be used in the M factor formula. This correction may be considered in two parts.

3.1 *Adjustment for power dissipation in the termination, Ct*

This is, in effect, a conversion from measured (power) gain to directive gain and is given for various configurations in Figs. 1*(a)* and 3*(a)*.

3.2 *Adjustment for current decay along the antenna, Cd*

This adjustment is necessary to convert (power) gain calculated from constant current formulae to a value more nearly in conformity with the measured values on actual antennae and is given, for the same configurations, in Figs. 1 *(b)* and 3 *(b)*. For convenience these curves are combined in Figs. 2 and 4, which enable the calculated (power) gain to be converted directly to directive gain. The full-line portions of these curves represent the normal design range.

All the curves are derived from measurements made on the power efficiencies of rhombic antennae described in Doc. III/21, 1966–1969, in which a linearly tapered current decay along the antennae was assumed. The antennae were of 3-wire construction having a surge impedance of 600 ohms. There is an important dependence of radiation efficiency upon surge impedance [2] and the lowest practicable value is desirable. Nevertheless there are constructional problems in reaching a value much below 600 ohms in the HF band.

4. Application

M-values for a number of antennae of various types are plotted in Fig. 5 and provide an indication of the variation with frequency of the performance of single antennae and antenna arrays, assessed from both measured (power) gains and from the gains calculated using the methods described in § 3. 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 $M = 0{\cdot}1f^2$. 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 standard 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 in [3], 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 of 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-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.

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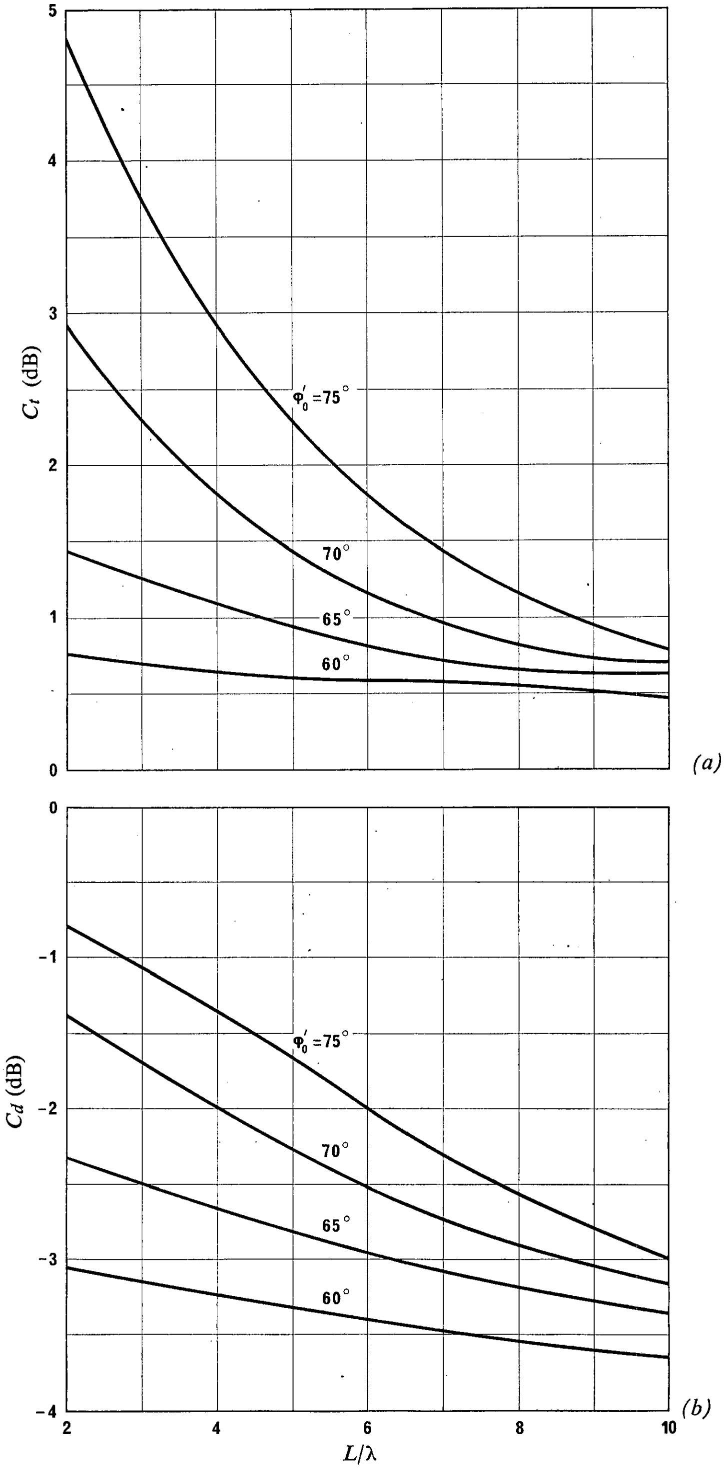
5
4
3
2
1
0
C_t (dB)
$\varphi_0' = 75°$
70°
65°
60°
(a)
0
-1
-2
-3
-4
C_d (dB)
$\varphi_0' = 75°$
70°
65°
60°
(b)
2
4
6
8
10
L/λ

FIGURE 1

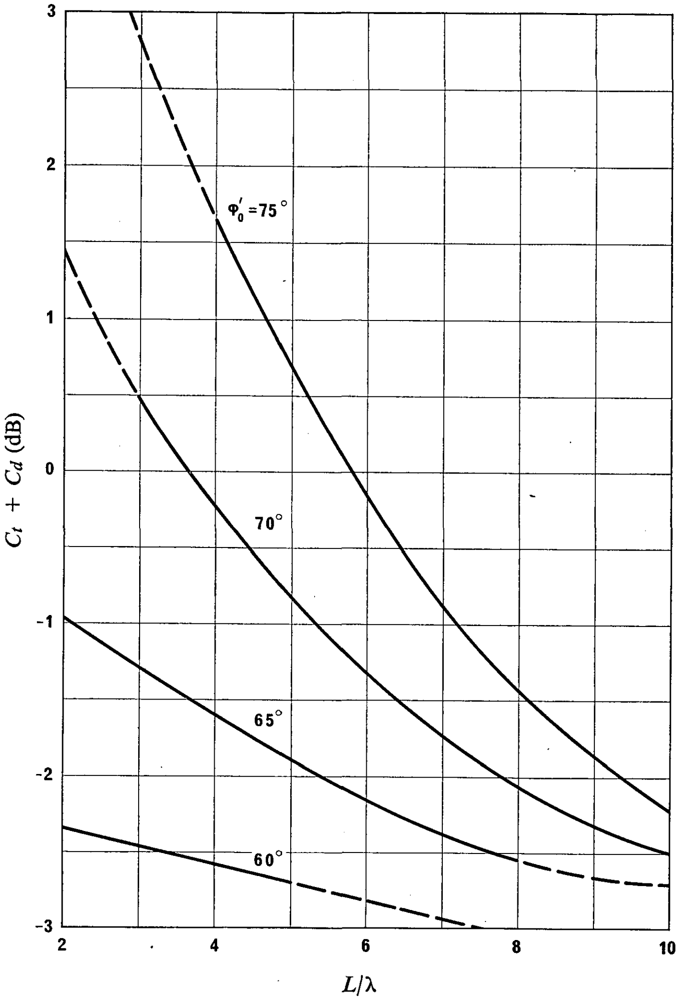

FIGURE 2

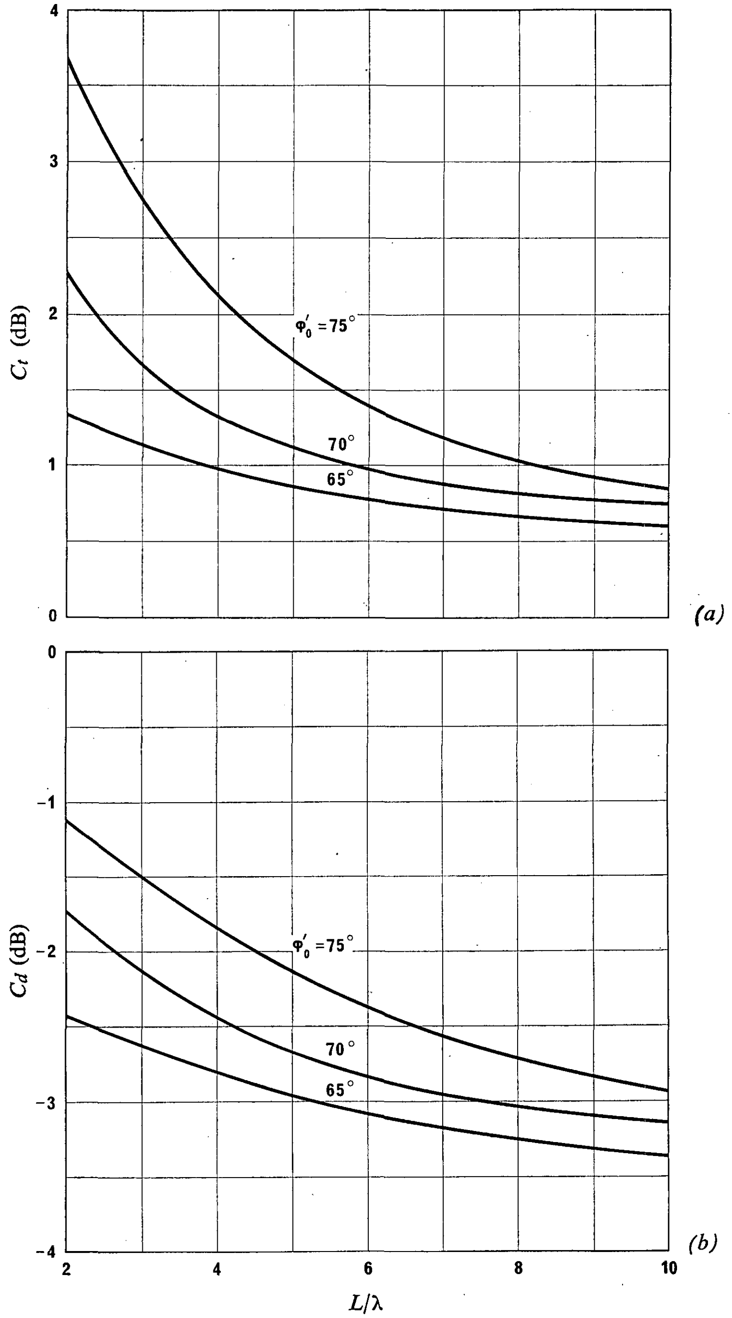
C_t (dB)
4
3
2
1
0
$\varphi'_0 = 75°$
70°
65°
(a)
C_d (dB)
0
−1
−2
−3
−4
$\varphi'_0 = 75°$
70°
65°
(b)
2
4
6
8
10
L/λ

FIGURE 3

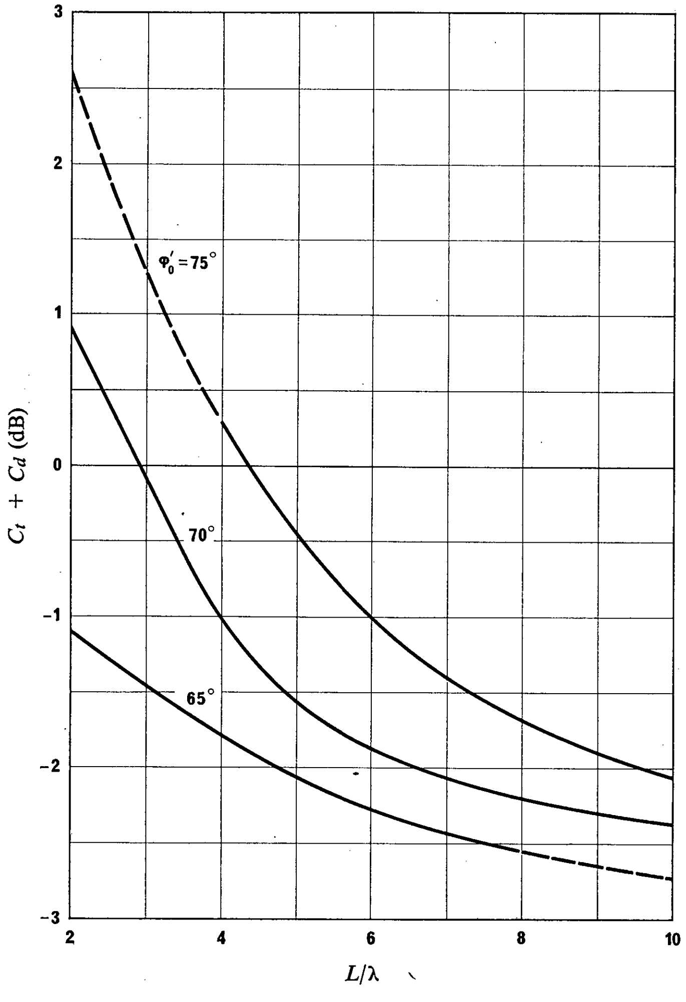

FIGURE 4

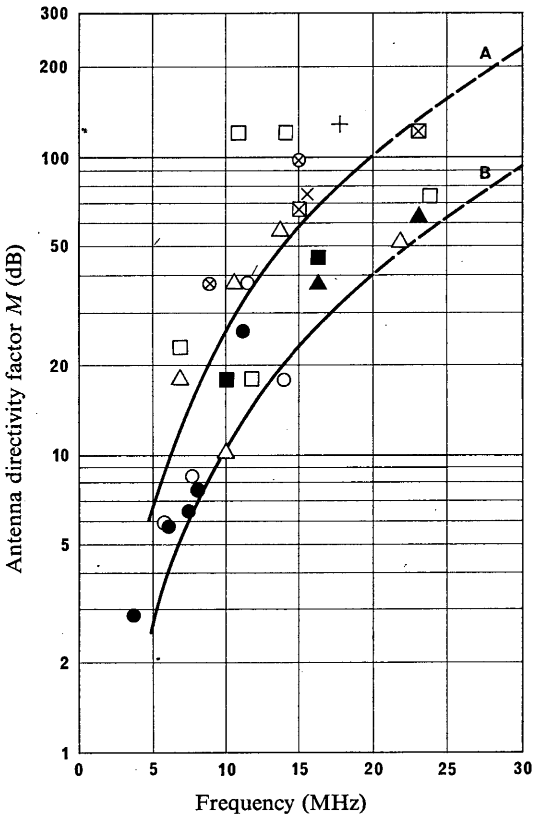

FIGURE 5

Antenna directivity factor, M, based on calculated gains

(see Recommendation 162-2)

Curve A: Economic standard antenna

○* Rhombic antenna 125 m/65°/45 m

□* Rhombic antenna 122 m/72·5°/23 m

} Complementary antennae

⊗ Rhombic antenna 158 m/71°/55 m

⊠ Rhombic antenna 158 m/75°/37 m

} Complementary antennae

Curve B: Minimum standard antenna

● Rhombic antenna 98 m/63°/45 m

■ Rhombic antenna 95 m/67°/32 m

▲ Rhombic antenna 90 m/69°/29 m

} Complementary antennae

△* Rhombic antenna 96 m/70°/23 m

×* Dipole array HR 4/4/1·0

+* Dipole array HR 8/4/0·5

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* Measured values of power gain, using airborne equipment.

REPORT 357*

OPERATIONAL IONOSPHERIC SOUNDING AT OBLIQUE INCIDENCE

(Study Programme 20A/3)

(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.

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* 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 433*

FACTORS GOVERNING THE CHOICE OF PILOT CARRIER LEVEL FOR INDEPENDENT-SIDEBAND RADIO EMISSIONS IN BAND 7 (HF)

(1970)

1. Introduction

Recent experience in the United Kingdom has led to the conclusion that the widely adopted practice of using a carrier level of –26 dB relative to peak envelope power in reduced carrier independent-sideband systems is leading to appreciable losses in circuit efficiency, particularly when such systems are used for the transmission of telegraph signals.

A review of the factors governing the level of pilot carrier necessary for independent-sideband transmissions therefore seems desirable.

2. Historical position

When single-sideband operation was first introduced on HF radiotelephone links, nearly 30 years ago, a pilot carrier of –16 dB relative to p.e.p. was used. With the introduction of independent-sideband working, which quickly followed, it was found necessary

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* This Report was adopted unanimously.

to reduce the carrier level by 10 dB to minimize inter-channel crosstalk due to non-linearity arising mainly in the high-power stages of the transmitter. For a number of years thereafter, the standard adopted by many Administrations was –16 dB carrier for single-sideband emissions and –26 dB for independent-sideband emissions. For the telephony emissions used at that time the lower carrier level provided adequate operation of the automatic frequency control and, with the increasing preponderance of independent-sideband emissions, the practice of increasing the carrier level for single-sideband emissions has tended to fall into disuse. The linearity of modern transmitters is much improved over that of transmitters which were in use at the time independent-sideband working was introduced.

A value of –20 dB relative to p.e.p. has been in use by the French Administration for some years.

Recently, the Lincompex terminal equipment has been coming into widespread use and with this development additional factors bearing on pilot carrier level are introduced.

3. Signal-to-noise ratios in sideband and carrier channels

3.1 *Channels with conventional terminals*

The minimum usable signal-to-noise ratio of a channel depends on its function. With a conventional terminal, only the speech channel and carrier channel need be considered while in the case of Lincompex equipment the control signal channel must be considered as well.

The carrier branch provides both automatic frequency control and automatic gain control functions. When the signal-to-noise ratio in the carrier branch is approximately 10 dB on an r.m.s. basis, the noise peaks will exceed the carrier peaks. Then large perturbations or even reversals of carrier phase will result so frequently as to impair operation of the automatic frequency control. This may be taken as the failure point of the carrier branch inasmuch as the automatic gain control is somewhat less affected by noise. The noise bandwidth of the carrier branch of a receiver varies among individual designs; for example in the United States of America it is commonly 35 Hz while in the United Kingdom it is 70 Hz and receivers used in the Netherlands, France and Japan have intermediate bandwidths.

The minimum usable speech-to-noise ratio depends on the type of terminal equipment used. For conventional terminals under stable circuit conditions a value of 15 dB corresponds to marginally commercial quality.* If these conditions and the foregoing ratio are assumed, the corresponding carrier-to-noise ratio can be calculated by taking into account the respective bandwidths of the speech and carrier channel and the mean speech level relative to p.e.p. Although the latter varies among Administrations, as well as the carrier filter noise bandwidth, such a calculation shows that, in the absence of selective fading, a carrier level of –26 dB relative to p.e.p. should be adequate to ensure that the automatic frequency control is not noticeably disturbed by noise before the speech channel of a conventional circuit becomes uncommercial.

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* See Recommendation 339-2.

Recent operating experience in the United Kingdom has shown, however, that if the carrier-to-noise ratio is increased by 10 dB some 5% improvement in commercial channel hours is nevertheless realized.

3.2 *Channels with Lincompex terminals*

In a Lincompex system, there is a possibility of inadequate signal-to-noise ratio in the speech channel, in the pilot carrier channel and/or in the control signal channel. The control signal channel has a bandwidth of 200 Hz and the speech bandwidth is correspondingly reduced from the usual 2750 Hz of a conventional circuit to 2450 Hz to accommodate both the speech and control signals below 3 kHz.*

High noise in the control channel causes the circuit loss to fluctuate. This imparts a subjective "gritty" quality to the speech. The effect becomes excessive for control channel signal-to-noise ratios less than about 14 dB.

A speech-to-noise ratio of 7 dB has been found to represent just marginally commercial quality, taking into account the compandor improvement.**

It can be calculated that the minimum usable signal-to-noise ratios occur approximately together in the speech channel, the control signal channel and the carrier channel.

Thus the protection afforded to the carrier is commensurate with that of the control channel if selective fading is ignored. Nevertheless, the importance of the carrier in controlling the gain stability of up to four channels would appear to demand a higher signal-to-noise ratio, since in the Lincompex system gain stability is directly related to the performance of the automatic frequency control system.

3.3 *Multichannel telegraph systems*

The failure of a radio-telegraph channel equipped with automatic error-control facilities is not rigidly definable since it depends on the circuit efficiency that can be tolerated. At low values of circuit efficiency undetected character errors increase significantly and, for this reason, low efficiency circuits are unsuitable for telex operation. For other types of telegraph traffic, however, circuit efficiencies as low as 20% to 30% may be considered tolerable in certain circumstances. However, for the purpose of this assessment, a circuit efficiency of 50% is taken as the failure point. For a dual-diversity system working typical radio conditions, this corresponds to a median signal-to-noise ratio of approximately 8 dB in the telegraph channel, which, in a typical 100-baud system, has a bandwidth of 140 Hz.

According to Recommendation 326-1, it is typical of present practice that the mean power of each channel of a multi-channel telegraph system (class of emission A7A or A7B) be given by p.e.p./$4n$, when $n>4$. Thus for a representative number of channels (say $4<n<10$), the power in a given telegraph channel will exceed that of a pilot-carrier of –26 dB relative to p.e.p. by at least 10 dB. But the carrier channel has an advantage with respect to noise bandwidth of only 3 to 6 dB since the ratio of the telegraph channel bandwidth to the carrier channel bandwidth is typically in range 2 to 4 (corresponding to a bandwidth range of 70 to

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* In accordance with Recommendation 455.

** See Note 5 to Recommendation 339-2.

35 Hz). Therefore it is evident that the carrier channel will be at a net disadvantage and that a pilot carrier level of –26 dB relative to p.e.p. is inadequate over a wide range of circumstances to ensure reliable action of the automatic frequency control down to the failure point of the telegraph system.

The foregoing discussion makes no allowance for selective fading. It may be noted that in general the telegraph channels ordinarily derive substantial benefit from either space or frequency diversity while the carrier channel does not.

4. Conclusions

An increase in pilot carrier level is desirable for independent-sideband and single-sideband systems carrying either telephone or telegraph signals or in the case of combined emissions. Since it would be desirable to standardize one value regardless of the type of traffic, the value of –20 dB relative to p.e.p. is recommended (see Recommendation 454).

SECTION 3B: RADIOTELEPHONY

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 335-2

USE OF RADIO LINKS IN INTERNATIONAL TELEPHONE CIRCUITS

The C.C.I.R., (1951 – 1963 – 1966 – 1970)

CONSIDERING

(a) that, at the present time, radiotelephone systems connecting the various countries often 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 the point of view of transmission performance, it is necessary to take special measures to ensure that the radio transmitter 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;

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

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 at frequencies less than 30 MHz, it is desirable to use single-sideband transmission to the maximum extent possible, to employ a speech 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 of the speech band 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 (voice-operated switching device), 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 an echo suppressor to avoid singing or echo disturbance on the complete circuit, or, preferably, with terminals using the principles of constant overall transmission loss, as set forth in Recommendation 455;

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 echo 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 this 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 336-2

PRINCIPLES OF THE DEVICES USED TO ACHIEVE PRIVACY IN RADIOTELEPHONE CONVERSATIONS

The C.C.I.R., (1951 – 1963 – 1966 – 1970)

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 MHz;

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* (see Note)

inverter systems, 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;

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.

Note. — The attention of Administrations is drawn to No. 465 of the Radio Regulations, which states:

> "**465** § 15. (1) Administrations are urged to discontinue, in the fixed service, the use of double-sideband radiotelephone transmissions in the bands below 30 Mc/s, if possible as from January 1, 1970."

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 2/3)

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 landline 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)*, 1 *(c)*, 1 *(d)*, 1 *(e)* or 1 *(f)*;

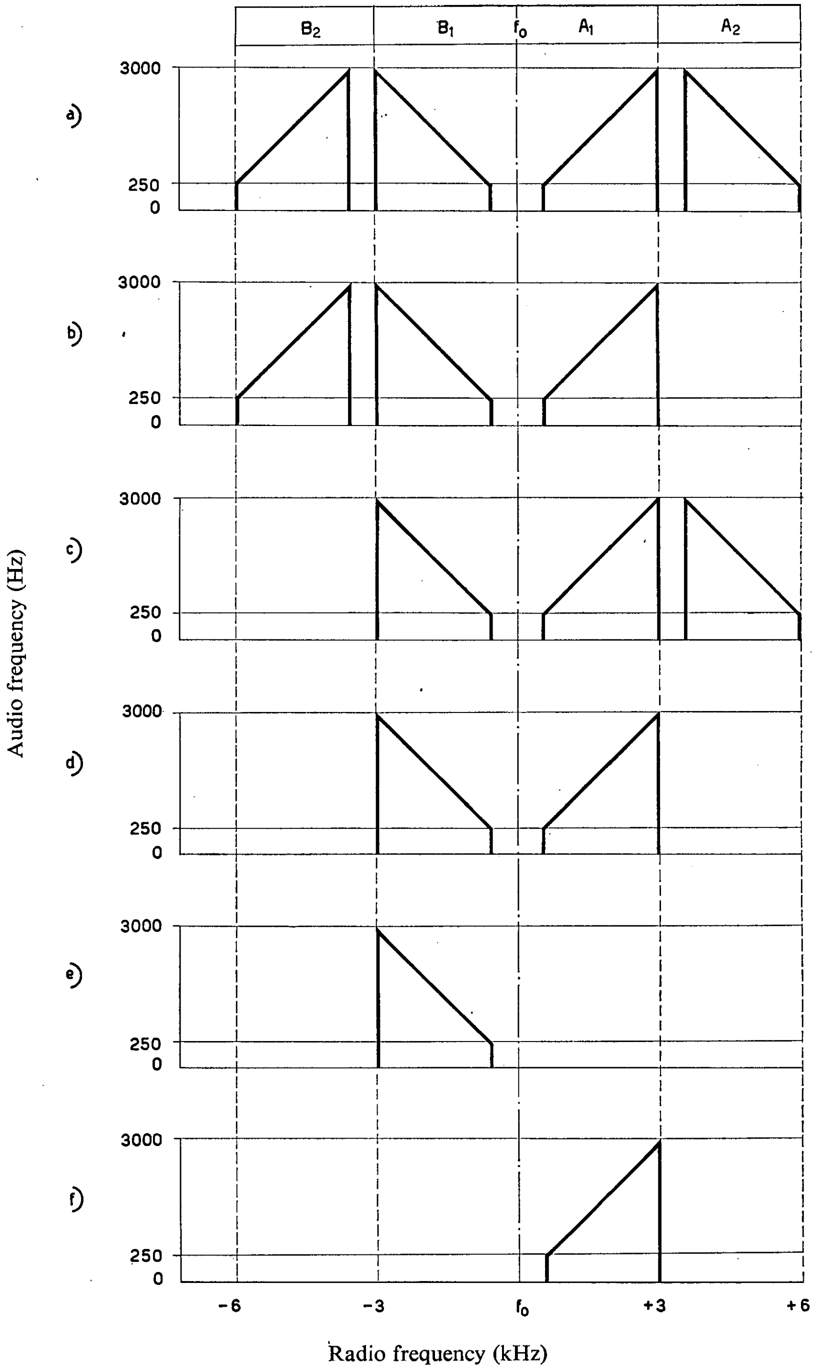


FIGURE 1

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 arrangements shown in Fig. 1*(d)*, a channelling arrangement such as that shown in Fig. 2 may be used to minimize cross-talk;

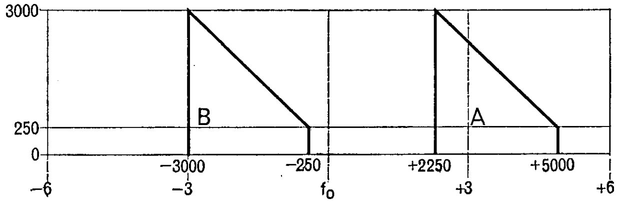


FIGURE 2

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

RECOMMENDATION 455

IMPROVED TRANSMISSION SYSTEM FOR HF RADIOTELEPHONE CIRCUITS

(Question 13/3)

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

CONSIDERING

(a) that, to maintain a satisfactory standard on international radiotelephone circuits operating at frequencies below 30 MHz and connected to the national network, it is necessary to compensate, at the transmitting end, for most, if not all, of the variations in the subscribers' speech volume and of the losses between the subscriber and the international exchange;

(b) that, as a result, the circuit often operates under a condition of overall gain (two-wire to two-wire) and it is necessary to use a singing-suppressor to maintain stability;

(c) that the singing-suppressor markedly degrades the performance of the circuit, due to its switching action and its tendency to misoperation by noise or interference on the radio path;

(d) that the use of a singing-suppressor to maintain overall stability of the radiotelephone channel inhibits the interconnection, on a four-wire basis (see C.C.I.T.T. Recommendation G.101) of radio circuits and long-distance cable or satellite circuits;

(e) that, if HF radiotelephone circuits were operated at a nearly constant overall transmission loss, the singing-suppressor could be eliminated and a radio circuit could be integrated into an international chain;

(f) that, to maintain a constant overall loss, while catering for variations in subscribers' speech volume and line loss, it is necessary to insert, at the receiving end of the circuit, a loss equivalent to the gain inserted at the transmitting end;

(g) that the advantages of compandor operation, as used on some line transmission systems, are well established, but cannot be directly realized on a radio circuit subject to fading;

(h) that, on such a radio circuit, an alternative means of conveying information as to the state of the compressor is necessary to control the expander;

(j) that these alternative means enable advantage to be taken of a compression ratio in excess of that employed in line compandors, which is generally 2/1;

(k) that the behaviour and advantages of a system employing a linked compressor and expander have been established (see Report 354-1);

(l) that with such an arrangement the two ends of a circuit will be complementary and the essential parameters of the system will have to be standardized;

UNANIMOUSLY RECOMMENDS

1. that, wherever possible, HF radiotelephone circuits should be operated on the basis of a constant overall transmission loss (two-wire to two-wire);

2. that a system comprising a compressor and expander linked by a control channel, which is separate from the speech channel and is resistant to fading distortion, should be used to achieve this performance;

3. that the system should maintain optimum loading of the transmitter at all times despite variations in subscribers' speech volumes and line losses;

4. that the speech and control signals should both be contained within a single 3 kHz channel;

5. that such a system should be in accordance with the description and parameters listed below:

5.1 *General*

For convenience, the performance requirements of this document are based on a system configuration (one end is shown in Fig. 1) which on the transmit side employs pre-compressor delay in conjunction with a voice-signal amplitude assessor. This does not preclude other configurations which meet the requirements.

5.2 *Transmit side (Fig. 1(a))*

5.2.1 *Speech channel*

5.2.1.1 *Steady-state conditions*

(compression and overall characteristics)

For input levels between +5 dBm0 to –55 dBm0 (Note 1) the output should lie within the limits shown in Fig. 2.

The overall amplitude/frequency response for the speech channel under both fixed-gain and assessor-controlled conditions at any level within the range +5 dBm0 to –55 dBm0 should be:

Above 250 Hz:	Attenuation relative to the maximum response in the band 250 to 2500 Hz (dB)
For frequencies in the band 250 to 2500 Hz	≤ 2
For frequencies in the band 2500 to 2700 Hz	≤ 6
For frequencies in the band 2800 Hz and above	>55
Below 250 Hz:	
Increase in overall gain for frequencies below 250 Hz	≤ 1

5.2.1.2 *Transient response*

(overall, including amplitude assessor but excluding additional delay)

Attack time, Fig. 3*(a)* (ms) (Note 2)	7 ± 2
Recovery time, Fig. 3*(b)* (ms) (Note 2)	20 ± 5

5.2.2 *Control channel*

Frequency-modulated oscillator
(frequency controlled by amplitude assessor output):

Nominal centre frequency (Hz)	2900 ± 1
Maximum frequency deviation (Hz)	± 60
Change of frequency for each 1 dB change of input level (Fig. 4) (Hz)	2
Input level to transmit side to produce nominal centre frequency (dBm0)	–25
Oscillator frequency resulting from an input level of 0 dBm0 (Hz)	2850
Oscillator frequency when there is no input to the transmit side (Hz)	≤2980
For sudden increases in the input that exceed 3 dB, the time taken for the oscillator to complete 80% of the corresponding change in frequency should be (ms)	5 – 7
For sudden decreases in the input that exceed 3 dB, the rate of change of oscillator frequency should lie between (Hz/ms)	1·5 – 3·5
Output spectrum effectively limited to (Hz)	2810 – 2990
Output level relative to test tone level in the speech channel (dB)	–5

5.3 *Receive side (Fig. 1(b))*

5.3.1 *Speech channel*

5.3.1.1 *Steady-state conditions*

The relative overall amplitude frequency response of the speech channel under fixed and controlled gain conditions should be:

Above 250 Hz:	Attenuation relative to the maximum response in the band 250 to 2500 Hz (dB)
For frequencies in the band 250 to 2500 Hz	≤ 2
For frequencies in the band 2500 to 2700 Hz	≤ 6
For frequencies in the band 2800 Hz and above (fading regulator at fixed gain)	>55
Below 250 Hz:	
Increase in overall gain for frequencies below 250 Hz	≤ 1

5.3.1.2 *Fading regulator*

Steady-state conditions

For input levels between +7 dB and –35 dB, relative to the nominal design input level to the fading regulator, the output should be within the limits shown in Fig. 5. The nominal design input level which may vary between Administrations is the value measured at the input of the fading regulator, under steady-state conditions, when 0 dBm0 is applied to the transmit side.

Transient response

Attack time: Fig. 3*(c)* (ms)	11 ± 2
Recovery time: Fig. 3*(d)* (ms)	32 ± 6

5.3.1.3 *Expander*

(controlled by the discriminator output)

Effective dynamic range (dB)	60

5.3.2 *Control channel*

5.3.2.1 *Amplitude/frequency and differential-delay characteristics of filter*

Attenuation within the band 2810 Hz to 2990 Hz (relative to that at 2900 Hz) (dB)	–1 to +2
Differential delay within the band 2840 to 2900 Hz (ms)	< 3
Attenuation below 2700 and above 3150 Hz (relative to that at 2900 Hz) (dB)	>55

5.3.2.2 *Discriminator* (Frequency/amplitude translator)

Characteristic at nominal control tone level

Changes in the expander output with changes in the frequency of the control tone between 2840 Hz and 2960 Hz, should lie within the limits shown in Fig. 6.

5.3.2.3 *Amplitude range of discriminator*

The performance quoted in § 5.3.2.2 should be met for control tone input signal levels to the discriminators from 0 dB to –30 dB relative to the nominal input level; with control tone input levels between –30 dB and –50 dB relative to nominal, an additional tolerance of ±1 dB could be added to the limits shown in Fig. 6.

5.3.3 *Overall attack and recovery time*

(A sudden change of 24 Hz in the frequency of the control tone is used to simulate a 12 dB step)

Attack time: Fig. 3*(e)* (ms)	20 ± 5
Recovery time: Fig. 3*(f)* (ms)	20 ± 5

5.4 *Equalization (overall) of transmission time*

To ensure a reasonable transmission standard, in particular of tone pulses, such as would be used for ringing or signalling, the overall transmission times of the speech and control channels should be equalized at the input to the expander to within 4 ms. In addition, the differential delay over the section of the passband of the speech channel, i.e., 250 Hz to 2500 Hz, should not exceed 4 ms.

To ensure that this can be achieved with independent designs of equipment, the time equalization provided should be divided equally between the transmit and receive sides of the equipment and should be adjustable so that the time delay encountered in privacy systems can be taken into account.

5.5 *Ringing and dialling*

Care should be taken to ensure that ringing and dialling signals are either passed completely through the equipment at both ends or completely by-pass both ends. The first method is to be preferred.

Note 1. — For definition of signal-to-test-level ratio (dBm0) see the relevant C.C.I.T.T. texts.

Note 2. — The definitions of attack time and recovery time which are similar to those defined by the C.C.I.T.T. for compandors (Recommendation G.162), are as follows:

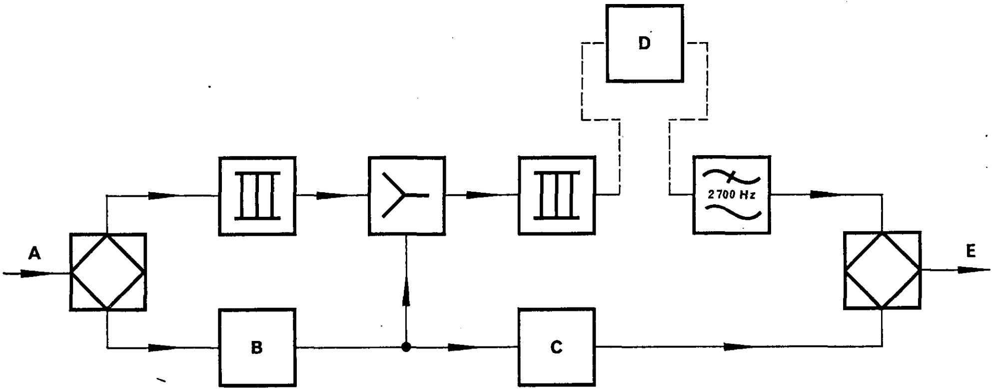
- *the attack time* of a compressor is defined as the time between the instant when a sudden increase of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 1·5 times its steady-state value;
- *the recovery time* of a compressor is defined as the time between the instant when a sudden decrease of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 0·75 times its steady-state value.

Note 3. — The parameters listed above are considered to be the minimum that should be agreed if compatibility between equipment is to be ensured. In addition, maximum tolerances have been quoted, but it has been assumed that these will not be used as design limits.

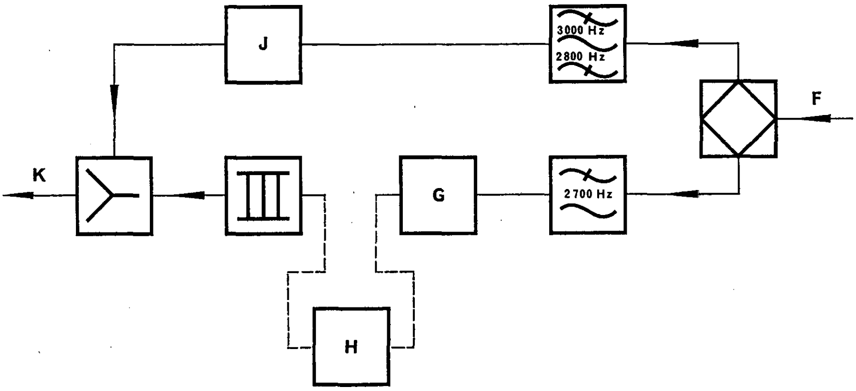
Note 4. — The temperature and power source variations with time, over which the parameters should be maintained, will vary between Administrations and have not therefore been included. The C.C.I.T.T., however, in their specification for compandors (Recommendation G.162), state that the performance should be maintained over a temperature range of +10°C to +40°C and with power source variations of ±5% of nominal.

Note 5. — Additional parameters which would normally be included in a specification for this class of equipment, i.e., input and output impedances and levels, signal-to-noise ratio, harmonic distortion, etc., have not been included as their value is not considered essential to compatibility between equipments. Administrations will wish to add their own values to ensure the satisfactory integration of the equipment into their own networks.

Note 6. — The type of transmission in the control channel according to this Recommendation is not considered as class of emission F3; therefore any provision of the Radio Regulations according to which class of emission F3 is prohibited for the fixed services in the bands below 30 MHz does not apply.



(a) Transmit side



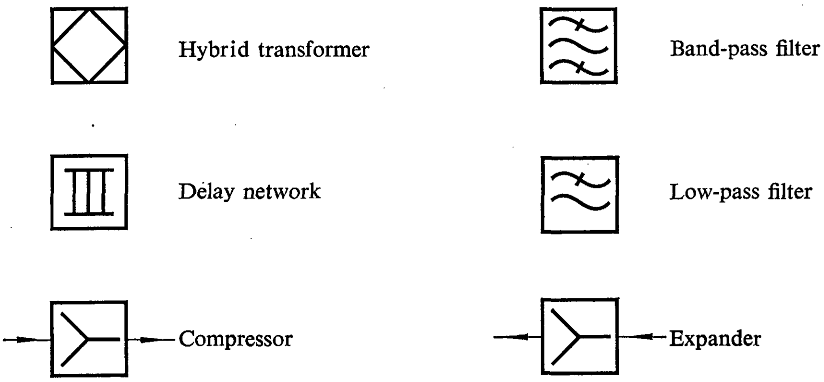
(b) Receive side

FIGURE 1

Schematic diagram of system

A: From landline
B: Amplitude assessor
C: Frequency-modulated oscillator
D: Privacy device
E: To radio transmitter

F: From radio receiver
G: Fading regulator (constant-volume amplifier)
H: Privacy device
J: Frequency discriminator
K: To landline



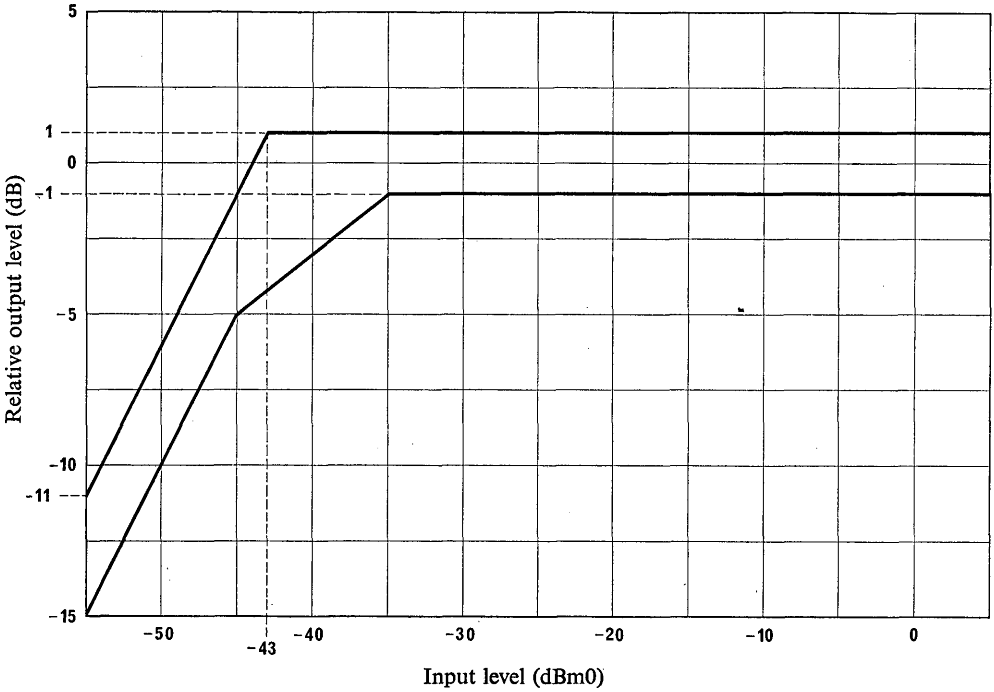
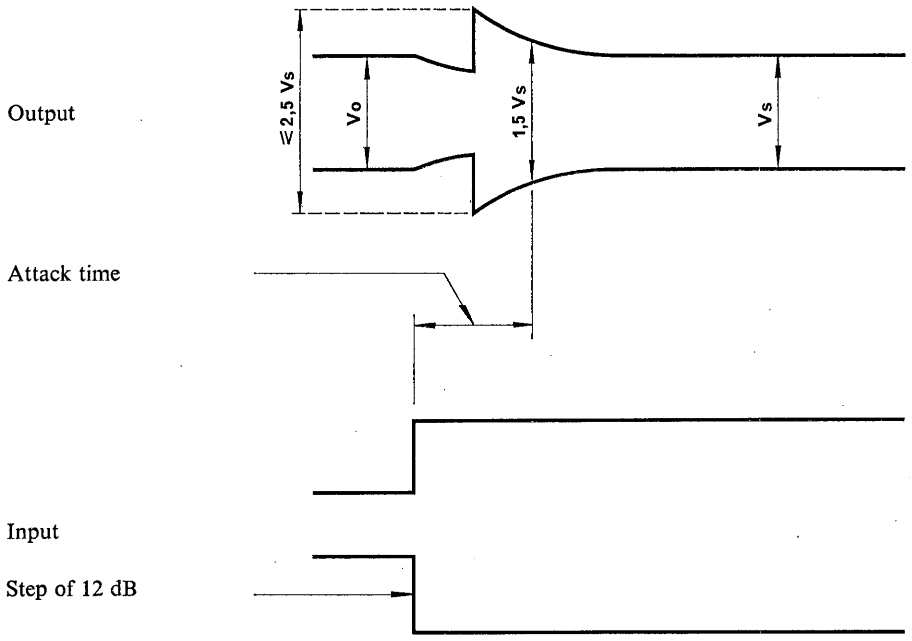
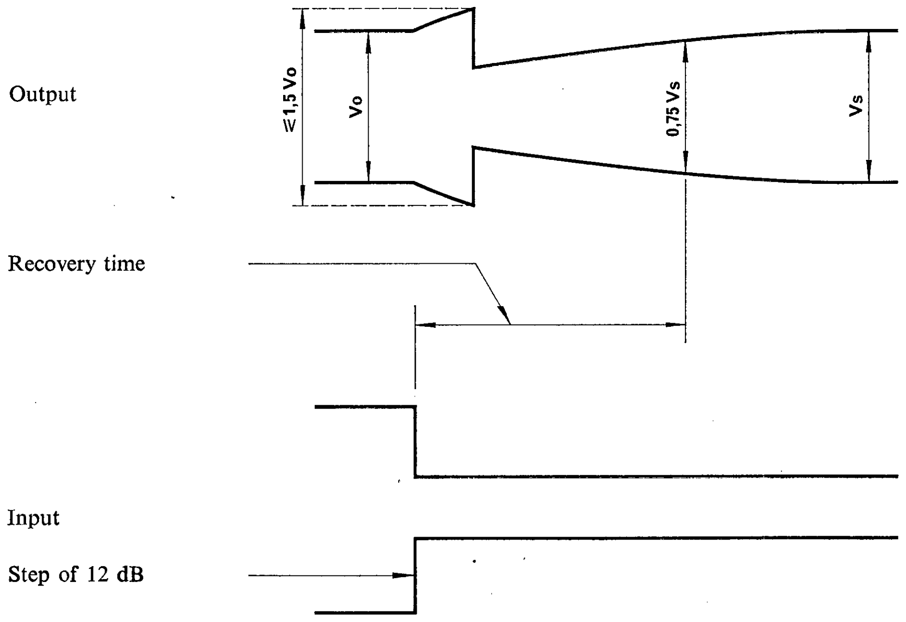


FIGURE 2

Input/output characteristic of transmit side



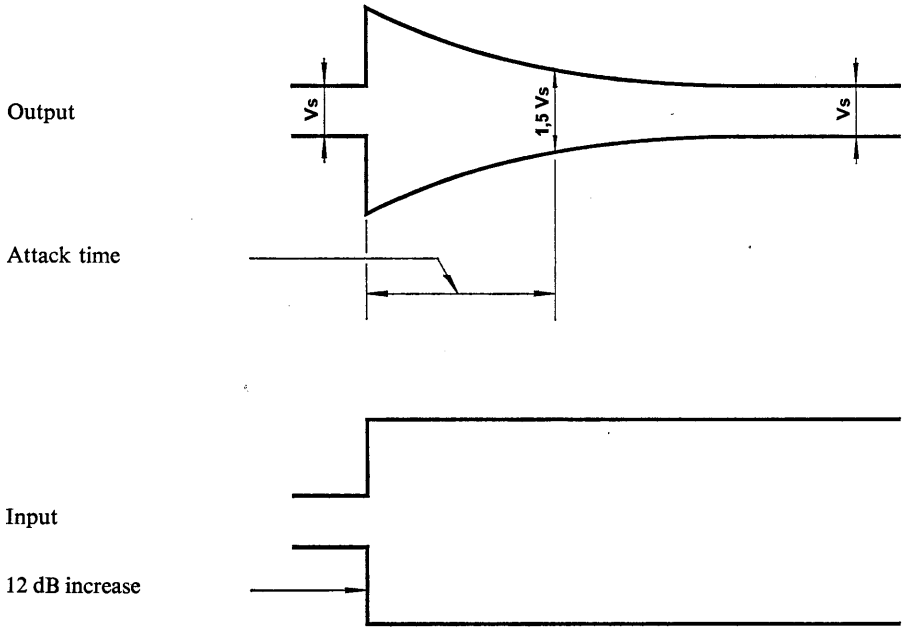
(a) Attack time



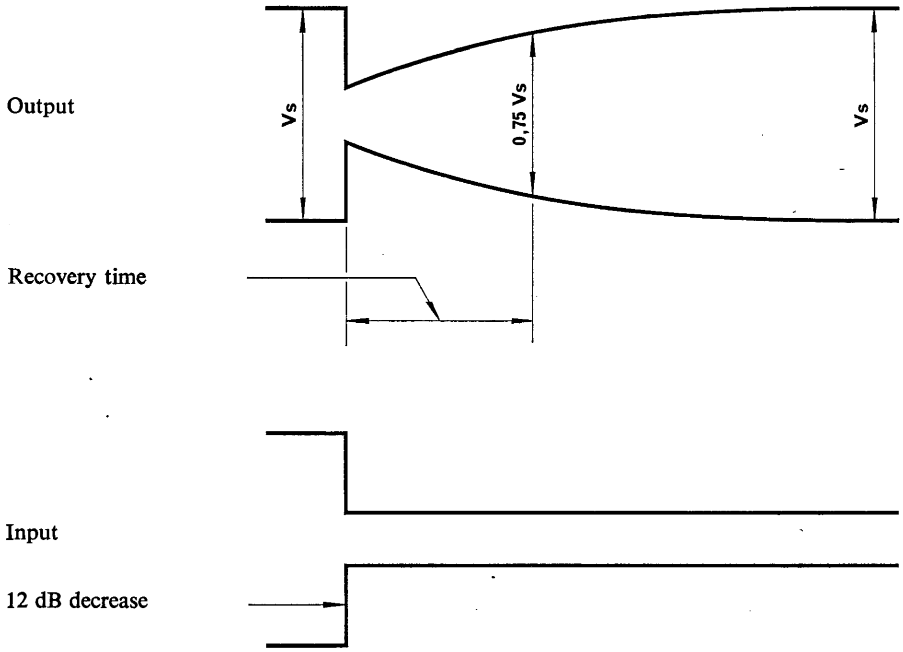
(b) Recovery time

FIGURE 3

Transient response of transmit side



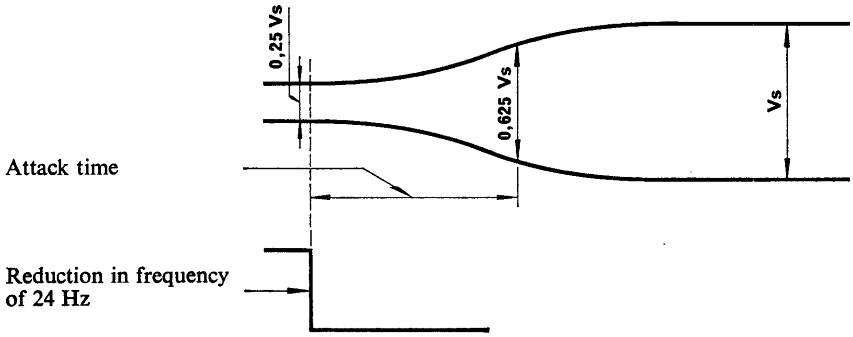
(c) Attack time



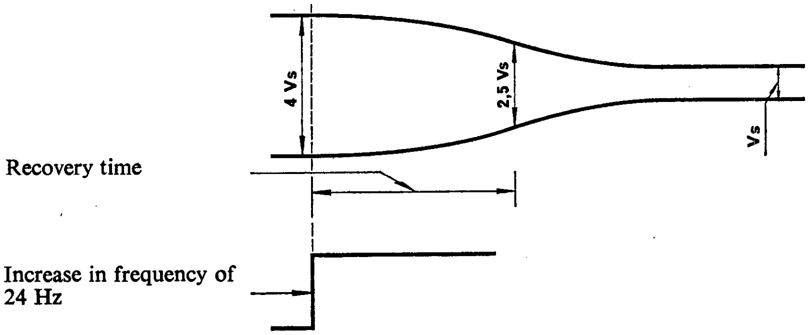
(d) Recovery time

FIGURE 3 (cont.)

Transient response of fading regulator



(e) Attack time



(f) Recovery time

FIGURE 3 (cont.)

Transient response of receive side

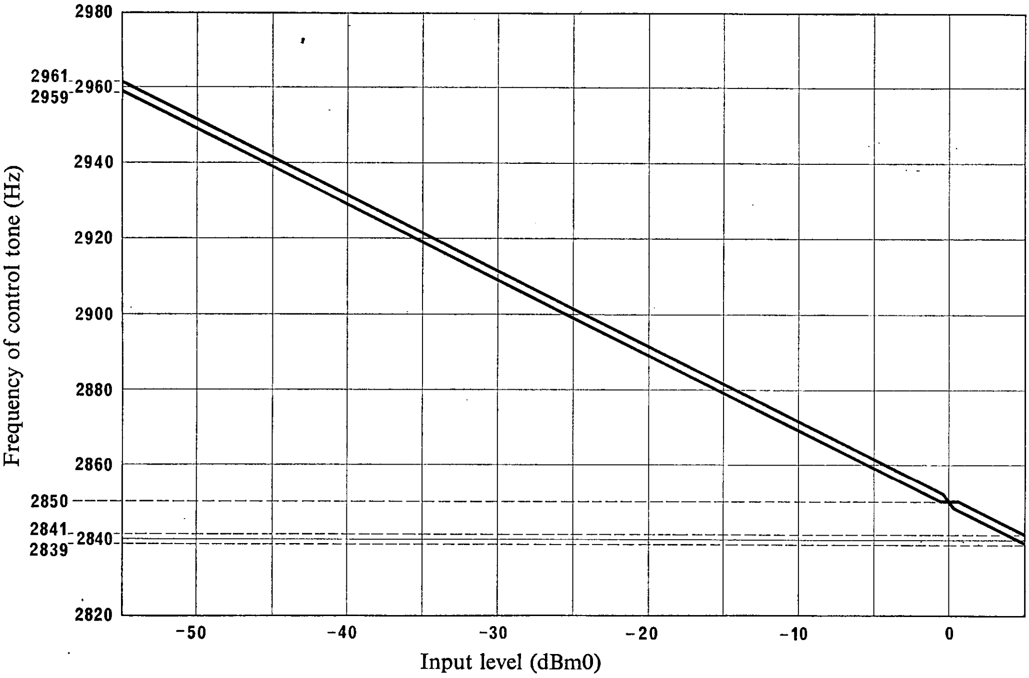


FIGURE 4

Variation in frequency of the control tone with changes of input level to the transmit side

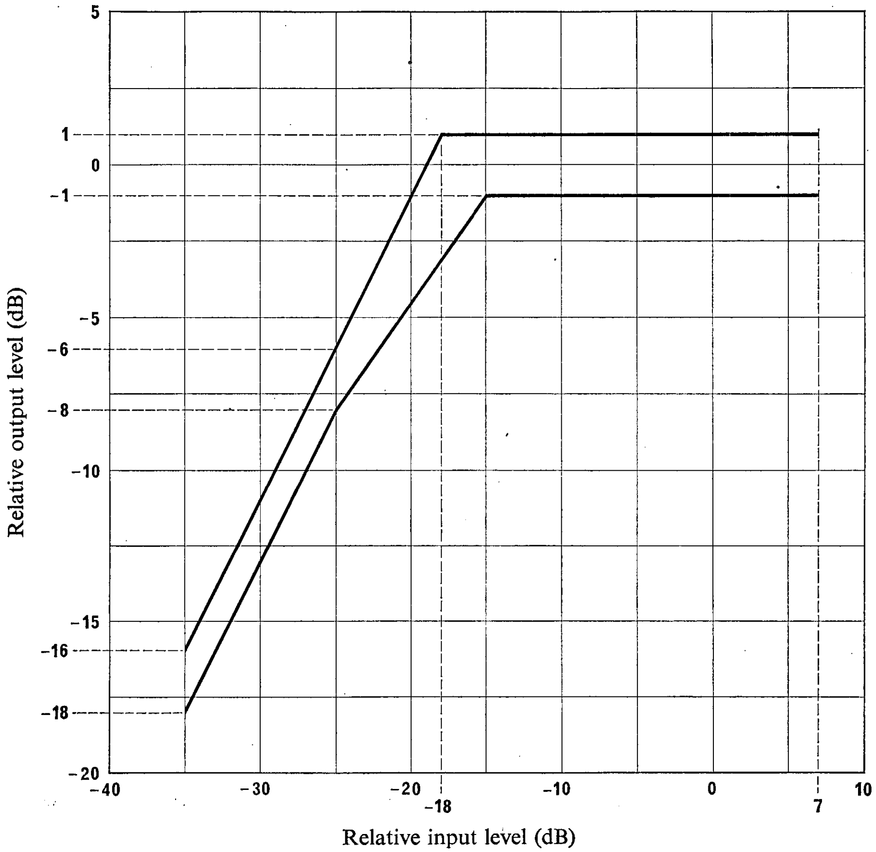


FIGURE 5

Input/output characteristic of fading regulator
(see § 5.3.1.2)

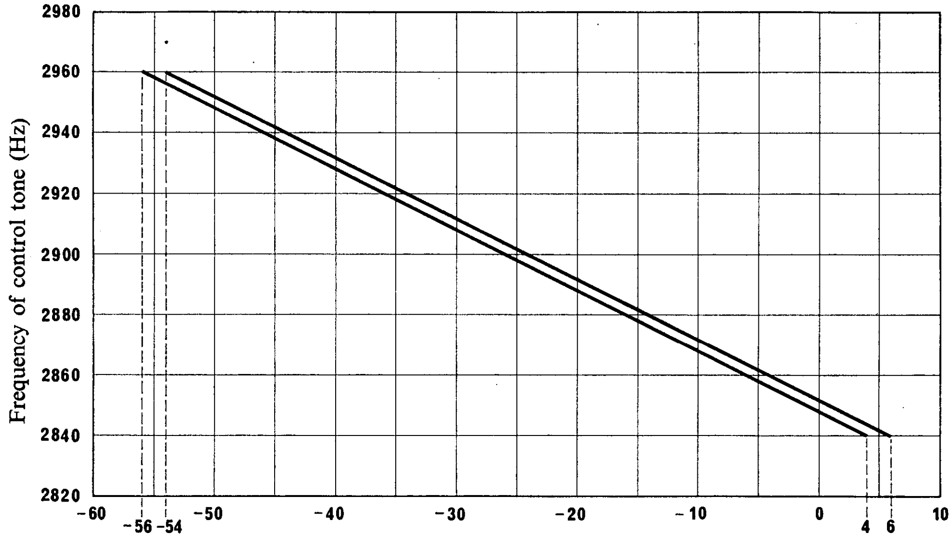


FIGURE 6

Variation in output level at the receiver side with change in frequency of the control tone
(see § 5.3.2.3)

3B: *Reports*

REPORT 353*

USE OF COMMON-FREQUENCY SYSTEMS ON INTERNATIONAL RADIOTELEPHONE CIRCUITS

(Question 19/1)**

(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.

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:

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* This Report was adopted unanimously.

** This Question replaces Question 9/III.

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	50 100 200	0·5 0·5 0·5	The a.f.c. was not affected up to a level of 50 mV
10	50 100 200	0·5 0·5 0·5	
15	50 100 200	0·5 0·5 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 passband 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 equipment, 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 335-2.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-2.	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 than –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. 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 335-2.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-2.	See Recommendation 335-2.
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.),	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

	antenna patterns, antenna radiation efficiency, transmitter power, etc.	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.

3. Suppressed carrier, single-channel operation

	Criteria	*Remarks*
3.1	*Recommendation .335-2.* The characteristics of the radiotelephone system shall be as specified in Recommendation 335-2.	See Recommendation 335-2.
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.)
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 354-1*

AN IMPROVED TRANSMISSION SYSTEM FOR USE OVER HF RADIOTELEPHONE CIRCUITS

(Question 13/3)

(1966 – 1970)

1. Introduction

Terminal apparatus currently employed on HF radiotelephone circuits includes constant-volume amplifiers and singing suppressors in each speech channel. 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 expander input.

During recent years a number of system techniques have been suggested** for overcoming the difficulties of using compandor principles on HF radio circuits. Most of these systems had the common feature that the voice signal is compressed and the information as to the degree of compression is transmitted over the circuit by means of a separate channel, to control the degree of expansion.

Docs. III/95 (United Kingdom) and III/99 (United States of America), 1963–1966, gave information on field trials with two similar, but not identical, systems and indicated the significant advantages that could be obtained over conventional systems by using compandor techniques.

Docs. III/7 (United Kingdom) and III/29 (United States of America), 1966–1969, describe detailed parameters of a "Linked Compressor and Expander" system called "Lincompex"*** and the principles are summarized as follows.

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 expander 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 the input level at the transmitting end,

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* This Report was adopted unanimously.

** See Bibliography.

*** The name "Lincompex" is neither a proprietary name, nor does it refer to a manufacturer of a particular equipment, but is a useful acronym for the phrase "linked compressor and expander", which describes the system.

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.

Preferred values for the parameters of the system have been given in Recommendation 455.

2. Field trials

Experimental equipment has been tested operationally at the terminal stations of the London-New Delhi radio circuit. The Lincompex equipment and the conventional terminal were applied to the *A1* and *B1* 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-equipped circuit gave consistently longer commercial time than the conventionally equipped circuit, 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.

Doc. III/19 (Japan), 1966–1969, describes field trials of a radioterminal equipment based on the same principles as Lincompex. Results of comparisons between the performance of a 600 km circuit between Tokyo and Osaka with the new equipment and with conventional VODAS equipment are given. Tests were made in February and August 1967.

In the first comparison, 29 persons participated in an opinion test to assess both speech quality and syllable articulation. Table I shows the results of this assessment, and indicates that the new equipment can provide a significant improvement in both quality and syllabic articulation. Test for syllabic articulation showed that the frequency of repetition with Lincompex was reduced to one-fourth of that obtained with conventional equipment.

TABLE I

Results of the field trial, February 1967

Test item	Grade	Evaluation	Experimental equipment (%)	Conventional equipment (%)
Opinion test	4	Excellent	58·6	31·0
	3	Good	34·4	37·9
	2	Fair	5·2	13·8
	1	Poor	1·8	13·8
	0	Unusable	0	3·5
Repetition	Repetition rate		0·4/100	1·7/100

In the second test, 85 participants engaged in test calls. Table II shows the summary of opinions, obtained by interview. As shown in the Table, 98·8% of the participants expressed the opinion that the HF radio circuit with the new equipment provides almost the same speech quality as a public telephone circuit routed over a cable or radio-relay system can do.

TABLE II

Results of listening test, August 1967

Items for interviews	Evaluation	Percentage of calls
Comparisons with public telephone	No difference	47·0
	Lincompex slightly worse than cable	51·8
	Lincompex much worse than cable	0
	No comment	1·2

3. "In service" performance

Docs. III/7 (United Kingdom), III/29 (United States of America) and III/30 (Republic of South Africa), 1966–1969, give information on the "in service" advantages obtained with Lincompex.

3.1 Doc. III/7 (United Kingdom) summarizes the results of special observations carried out by trained personnel on the London – Nairobi and London – Johannesburg circuits. Comparisons were made between a channel fitted with the new arrangement and a conventional channel in the same 4-channel group.

The results may be summarized as follows:

increase in number of calls passed compared with conventional channels	100%
increased chargeable time per call	6% (88% to 94%)
increased average length of call	6%
percentage of calls graded "smooth" increased by	25% (60% to 85%)

This greatly enhanced circuit efficiency was achieved with reduced attention by the traffic operator, it being found practicable for the "incoming" operator to retire once the called number had been dialled, leaving the "outgoing" operator to control the call. No supervision by technical operators was employed at either end. It is significant to note that the percentage paid time per call is now high enough to eliminate the need for observation and timing, and calls can be set up as for a line circuit.

3.2 Doc. III/29 (United States of America) summarizes the improvements that have been obtained with "in service use" of Lincompex equipment since July 1966. Since then regular commercial services using one or more Lincompex systems have been established between the United States and a number of other countries. User reaction has been swift, with favourable comments on the easy flow of conversation and the lack of noise.

In general, one or two Lincompex-equipped channels have been assigned to a particular four-channel radio system. Thus, the increase in commercial time on any given frequency has not been readily observable; the demands of the conventionally equipped channels caused frequency changes to be made prior to that needed by the newly equipped channels. However, it was observed that when the newly equipped circuits were controlling, they remained in service long after the conventional channels were unserviceable. The estimated increase in usable circuit time was from 16% to 20%.

Analysis of traffic patterns on trunk groups having Lincompex-type equipped channels on one or more circuits indicate the following:

— the Lincompex channel handled 26% of the total number of calls in a 12-channel trunk group: almost that of the next three busiest channels in the group;

— the increase in minutes per call on the Lincompex-equipped channel amounted to 16·5%;

— the Lincompex channel accounted for 29% of the chargeable minutes in a 12-channel trunk group.

3.3 Doc. III/30 (Republic of South Africa) comments upon the advantages that have been obtained by the use of Lincompex equipment on the Johannesburg – London circuit over the period September, 1967 to May, 1968. It draws attention to the possibility of staff reductions, as little or no monitoring is required, and the improvement in the quality of reception of special news "broadcasts" which in general is, with Lincompex, of a sufficiently high standard to permit of retransmission without further processing, or, in some cases, being re-read locally.

A detailed description is given of the arrangements made to compare a Lincompex circuit with a conventional circuit. The analysis is based on calls passed from Johannesburg to London. The results are given in Table III, from which it will be seen that the Lincompex-equipped circuit carried nearly twice as much traffic as the normal circuit, during the months under consideration.

Considering that the service time of the Lincompex-equipped circuit was longer than that of the normal circuit and that, during March, 241 calls were passed over the Lincompex circuit during the period when the normal circuit was closed, it is concluded that the Lincompex-equipped circuit carried, on average, about 25% more traffic than the normal circuit over the same period of time. The opinion is given that the reason for the higher traffic carrying capability of the Lincompex-equipped circuit is that less time is required by the traffic operators to pass call details.

Table IV shows the relative grade of service offered by the new system during the period 0700 to 2000 GMT when propagation conditions are stable. The marked improvement noticeable with the Lincompex channel is due to the greater ease of conversation and general absence of noise due to the compandor action. The traffic operator remarked particularly on this aspect of performance.

To determine the extent of the improvement in traffic time which could be expected from the use of Lincompex equipment, special tests were conducted throughout the 24-hour day.

Table V indicates the results of these tests.

Although the Lincompex circuit shows practically no improvement in commercial time over the normal circuit between 0600 to 1800 GMT, it provides a circuit which is quiet, for a greater percentage of the available time. During the less stable periods 0000 to 0600 GMT and 1800 to 2400 GMT, the Lincompex circuit is superior in providing a circuit which is not only quiet for a greater percentage of the available time, but also commercial for a greater percentage of the available time.

The document concludes by summarizing the improvements as follows:

— less time required by traffic operators for passing details of booked calls, and consequently a higher traffic carrying capability,

— easier conversation, and consequently a higher percentage effective circuit time,

— transmission of news items of a standard which permits retransmission to broadcast listeners, thus obviating the necessity to re-read locally,

— very little maintenance,

— a minimum of attention by the technical operators.

Effective duration of calls = Overall duration minus time allowed for repetitions

TABLE III

	Number of calls passed					Duration (min)		Average duration (min)	Percentage effective time
	Jan.	Feb.	March	April	Total	Overall	Effective		
Lincompex	719	633	1198	244	2794	15 574	15 478	5·57	99·38
Normal	377	336	27	719	1459	7836	7518	5·37	95·94

TABLE IV

Period 0700–2000 GMT	Good, quiet (%)	Slightly noisy, commercial (%)	Noisy, uncommercial (%)	Slight interference commercial (%)	Interference uncommercial (%)	Uncommercial due to frequency changes, equipment and line failures (%)	Total time commercial (%)
Lincompex	92	3·9	1·2			2·9	95·9
Normal	66·7	24·6	4·1	1·7		2·9	93·0

Table V

Period		Good, quiet (%)	Slightly noisy, commercial (%)	Noisy, uncommercial (%)	Slight interference commercial (%)	Interference uncommercial (%)	Uncommercial due to frequency changes, equipment and line failures (%)	Total time commercial (%)
0000 to 0600 GMT	Lincompex	57·3	19·7	15·0	1·2		6·8	78·2
	Normal	7·6	22·5	15·3	1·5	46·3	6·8	31·6
0600 to 1800 GMT	Lincompex	96·4	1·3	1·0			1·3	97·7
	Normal	70·0	26·6	2·1			1·3	96·6
1800 to 2400 GMT	Lincompex	57·2	24·6	8·4	0·4	1·1	8·3	82·2
	Normal	7·7	32·3	22·2		29·5	8·3	40·0

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REPORT 355-1*

USE OF DIVERSITY ON INTERNATIONAL HF RADIOTELEPHONE CIRCUITS

(Question 13/3)

(1966 - 1970)

1. Introduction

This Report discusses some diversity techniques for the HF radiotelephone service, including wide-spaced diversity, in-band diversity, and time diversity.

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* This Report was adopted unanimously.

2. Wide-spaced diversity for voice operation

In addition to the absence of correlation in the fast phase-interference fading of radio-frequency signals at receiving stations separated by a number of miles, there is some lack of correlation in the slower fading. To investigate the latter, interstation tests were made, over a telephony link from Amsterdam, operating at 18 MHz in class of emission A3A, with receivers at two sites in New Jersey about 135 km (85 miles) apart.

The antenna outputs were recorded over the operating hours of a period of ten months, using equipment having a time constant of 40 s. Analysis of the charts showed:

- signal strength differences up to 10 or 20 dB and lasting for an hour or more were not uncommon, despite the fact that there was a strong correlation between the general (hourly median) levels at the two sites, both during normal and magnetically disturbed days;
- as was to be expected, the interstation diversity would not have helped appreciably against sudden ionospheric disturbances;
- in general, on days when the overseas transmission was disturbed, the interstation improvements, in decibels, on the average did not differ greatly from that obtained on other days
- the distribution of the simultaneous differences, in decibels, between the antenna outputs, approximated closely to the normal;
- the standard deviation of this distribution (for an analysed period of about three months) was 8·5 dB. The correlation between the two outputs was about 0·85;
- the average difference (for this period) was 0 dB;
- the average of the signal improvement, in decibels, useful half of the time, was 7 dB. During two-thirds of the time that one branch signal was depressed more than 20 dB from the median, the average improvement was greater than 8 dB; and for 15% of this time, greater than 23 dB.

To utilize the potential signal-to-noise improvement, an automatic selecting arrangement and the necessary additional wire lines would have to be used. The amount of lost circuit time resulting otherwise from poor radio transmission which would be reclaimed by the interstation diversity would depend upon the value, relative to the median value, of the signal strength representing the commercial limit. The latter, in turn, depends largely upon the noise. To the degree that the effective noise input to the receiver is constant, as it tends to be if set noise, or to a lesser extent cosmic noise, is controlling, the distributions of signal-to-noise ratio would tend to have the same variances as those of the signals. On this basis, and assuming an ideal selecting and utilizing system, the fraction of lost circuit time reclaimed on the 18 MHz Amsterdam circuit would have been roughly one-third.

The method is also effective in the case of co-channel interference from a distant undesired station. During the tests a marked diversity effect between Amsterdam signals and those of a co-channel interfering telegraph station in Europe was observed. The telegraph signal was present in the Amsterdam channel sometimes for hours, and during these periods, its intensity relative to the Amsterdam signal was observed to vary over wide ranges. There were also large differences at times between the outputs of the antennae at the two receiving sites on these telegraph signals, and still larger differences at the outputs of the receivers whose gains were controlled by the Amsterdam signals. This "compounded" diversity effect was so great at times that the interference might render one receiver uncommercial and at the same time be hardly audible on the other. This effect may become increasingly important in problems in the future when radio reception may be increasingly limited by unwanted signals other than radio noise (see Report 414).

In addition to the foregoing tests, a comparison of several thousand paired measurements of the signal-to-noise ratio at the two sites, using similar receiving antennae on a London circuit, was made. The estimated average diversity improvement, useful half of the time, which an ideal selecting system would have yielded was 5·5 dB. Data for several operating frequencies were lumped together in arriving at this result. The 5·5 dB value can be compared with the 7 dB figure given above for the Amsterdam tests at 18 MHz and based upon signal recordings alone rather than recordings of the signal-to-noise ratio.

Subsequently, an experimental comparator to select the better receiver branch was used. Briefly, this comparator measures the received noise and interference during outgoing speech (under the control of the VODAS), and selects the output of the quieter receiver. The time constants are such that the switch does not operate on isolated impulse noise peaks. The noise outputs of both the accepted and rejected branches were recorded on a dual pen recorder which was equipped also with an event recording pen to provide a continuous record of the switch position. An example of noise distributions for the accepted branch, and the rejected branch, as derived from recordings covering portions of three days, is shown in Fig. 1. This short sample is, of course, inadequate to represent results over a much longer time.

No effort was made to determine the correlation of the slower fading as a function of the separation of the receiver sites. In addition to separation, topographical differences of a kind which would affect the directional response of the antennae differently would influence the results.

The improvement afforded by wide-spaced diversity may justify its use on some important 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. 2.

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 bandpass 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.

4.1 Doc. III/22 (Federal Republic of Germany), 1966–1969, describes tests carried out over a New York–Frankfurt radiotelephone circuit. In this test, the audio-frequency outputs of two space-diversity receivers were separated by splitting them into five bands 550 Hz wide, by means of the filter units of an ordinary privacy equipment. A switching device selected from each of the five pairs of corresponding frequency bands the branch with the greater amplitude. The combined diversity telephone signal was then compared with the by-passed non-diversity outputs from the two receivers. Special care was taken to eliminate the influence of differing characteristics of the two receivers and extension circuits, the selection devices and the tape recorders.

The results of the tests may be summed up as follows:

- for "barely acceptable commercial quality" with dual-diversity reception and the selection of five partial bands, the method reduces the fading probability, or the proportion of fading time in the service period (fading depth $\geq$ 10 dB below the median value) to about 20% of the value without selection;

- extension to multiple-diversity reception and sub-division into a larger number of partial bands than used in the tests would not appreciably increase efficiency;
- the method leads to a substantial increase in speech fidelity, but to no perceptible increase in intelligibility. It is supposed therefore that the improvement in logatome clarity, which is near the perceptibility threshold, cannot be more than a few per cent;
- the higher the quality of transmission, for instance, as characterized by the articulation index [2], the smaller the improvement that can be obtained. It would therefore seem better to use methods which effectively increase the signal-to-noise ratio to momentary speech values (Lincompex, or constant net loss operation).

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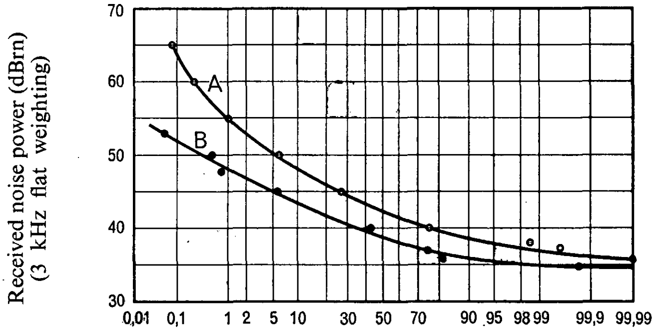
2. Fletcher, H. *Speech and hearing*. D. van Nostrand Company, Inc., New York, London (1953).



Percentage of the time that the noise is equal to or greater than the ordinate

Figure 1

Wide-spaced diversity, 16 430 kHz, 11 to 13 June, 1962.
Receiving stations at Manahawkin and Netcong, N. J.

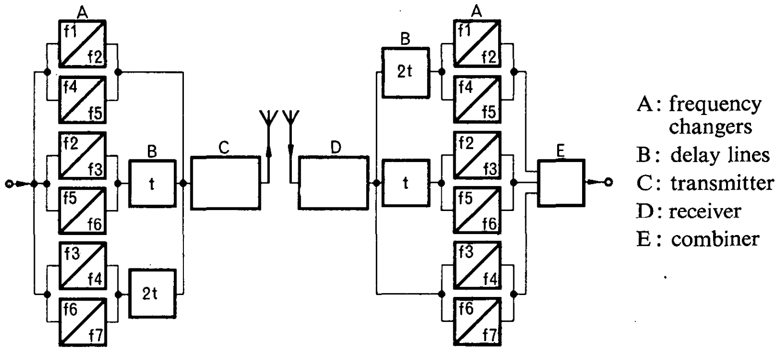


Figure 2

Simplified block diagram of Echoplex

REPORT 434*

TRANSMISSION CHARACTERISTICS OF HF RADIOTELEPHONE CIRCUITS

(Question 16/3)

(1970)

In view of the difficulty of connecting HF radiotelephone circuits to international automatic exchanges using C.C.I.T.T. signalling code No. 4 or No. 5, the French P.T.T. Administration, convinced of the advantages of semi-automatic operating, developed and brought into use in 1966 semi-automatic numbering devices which are based on the following principles:

A circuit is specially assigned for traffic between OUTGOING country A and INCOMING country B. The information given by the operator in country A – seizing, numerical, clear-forward – is converted into voice-frequency signals by a device placed in the radio terminal centre. The signals are transmitted in this form to the other terminal, where a receiving device restores the outgoing signals and performs the seizing, dialling etc. at the automatic switching equipment in country B, just as a subscriber in that country would do. The operator at A is thus “remote-connected” to the switching system in country B.

The transmitting and receiving devices required can be accommodated in the network connection cabinets at both terminals without any adaptation of these equipments.

This system has proved entirely satisfactory and its use is limited only by the quality of the channel used for the call. It is being introduced on a wide scale by the French Administration.

The aim of the Annex is to list the various signals used for transmitting the required information.

ANNEX

The Table below describes the various signals used for transmitting information between the two numbering devices:

- the TRANSMITTING device (placed at the “transmit” output of the network connection cabinet in country A, and connected to the operations room);
- the RECEIVING device (placed at the “receive” input of the network connection cabinet in country B, and connected to the automatic switching equipment).

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* This Report was adopted unanimously.

Information	Signal	Modulation	Duration
Seizing(¹)	Frequency modulated voice frequency signal 1980 Hz with a deviation of ±90 Hz	50 Hz	300 ms
Dialling*(¹)		At the dial pulse rate (66/33 ms)	
End-of-dialling(²)		50 Hz	300 ms
Clearing(¹)		50 Hz	650 ms

(¹) Information supplied by the operator in the operations room.

(²) Information supplied by the internal logic of the *Transmitting* device. This particular signal is not designed to be sent to the automatic switching equipment but it enables the two numbering devices to reconnect the network connection cabinets so that the call may take place. During the conversation, the clearing detector alone, which is not susceptible to telephone currents, remains live in the *Receiving* device.

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* Study Group 3 suggests consultation with C.C.I.T.T. to determine whether the alternative term "numbering" is to be preferred.

SECTION 3C: RADIOTELEGRAPHY AND FACSIMILE

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 106-1

VOICE-FREQUENCY TELEGRAPHY ON RADIO CIRCUITS

The C.C.I.R., (1953 - 1970)

CONSIDERING

(a) 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;

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

(c) 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;

(d) that space or polarization 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;
2. that, whenever practicable, space or, possibly, polarization 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 246-2

FREQUENCY-SHIFT KEYING*

(Question 8/3)

The C.C.I.R., (1951 - 1953 - 1956 - 1959 - 1966 - 1970)

CONSIDERING

(a) that frequency-shift keying is employed in radiotelegraphy in the fixed 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;

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* For the use of frequency-shift keying in the maritime mobile service see Appendix 20B (Mar), § (*c*) of the Radio Regulations.

(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 still employed in some 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.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 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;

2. 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, 340 Hz, 400 Hz* and, for modulation rates above 250 bauds, 500 Hz;

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

4. that the value of the frequency shift should, if possible, be maintained within ± 3% of its nominal value and, in any case, within ± 10%;

5. 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;

6.** that for circuits using the International Telegraph 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*);

7.** that, for telex circuits using the International Telegraph 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*);

8.** that for channels of a 7-unit automatic error-correcting system, referred to in Annex I to Recommendation 342-2, the higher frequency should correspond to the aggregate signal condition *B* and the lower frequency to the aggregate signal condition *Y*.

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* The value 170 Hz is used in the maritime mobile service, see Appendix 20B (Mar), § (*c*) of the Radio Regulations and Recommendation 440-1, § 4.

** 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.

RECOMMENDATION 342-2

AUTOMATIC ERROR-CORRECTING SYSTEM FOR TELEGRAPH SIGNALS TRANSMITTED OVER RADIO CIRCUITS

(Study Programme 18A/1)*

The C.C.I.R., (1951 – 1953 – 1956 – 1959 – 1963 – 1966 – 1970)

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 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;

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

(k) 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;

(l) 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;

(m) 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;

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* This Study Programme replaces Study Programme 5A/III.

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	International code No. 3
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 Figs. 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 Figs. 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. Designation of aggregate signal

To assist in identifying the signal condition when applying the aggregate telegraph signal to modulate the radio channel, the following designation for the aggregate signal should be used:

TABLE III

Seven-unit code condition	Aggregate signal condition	
	Erect character	Inverted character
A	B	Y
Z	Y	B

6. 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.

7. Automatic phasing

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

7.1.1 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;

7.1.2 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;

7.2 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*.

8. 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 IV.

TABLE IV

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

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-baud 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 $\pm 1 \times 10^{-6}$.

9. 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:

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

9.2 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;

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

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

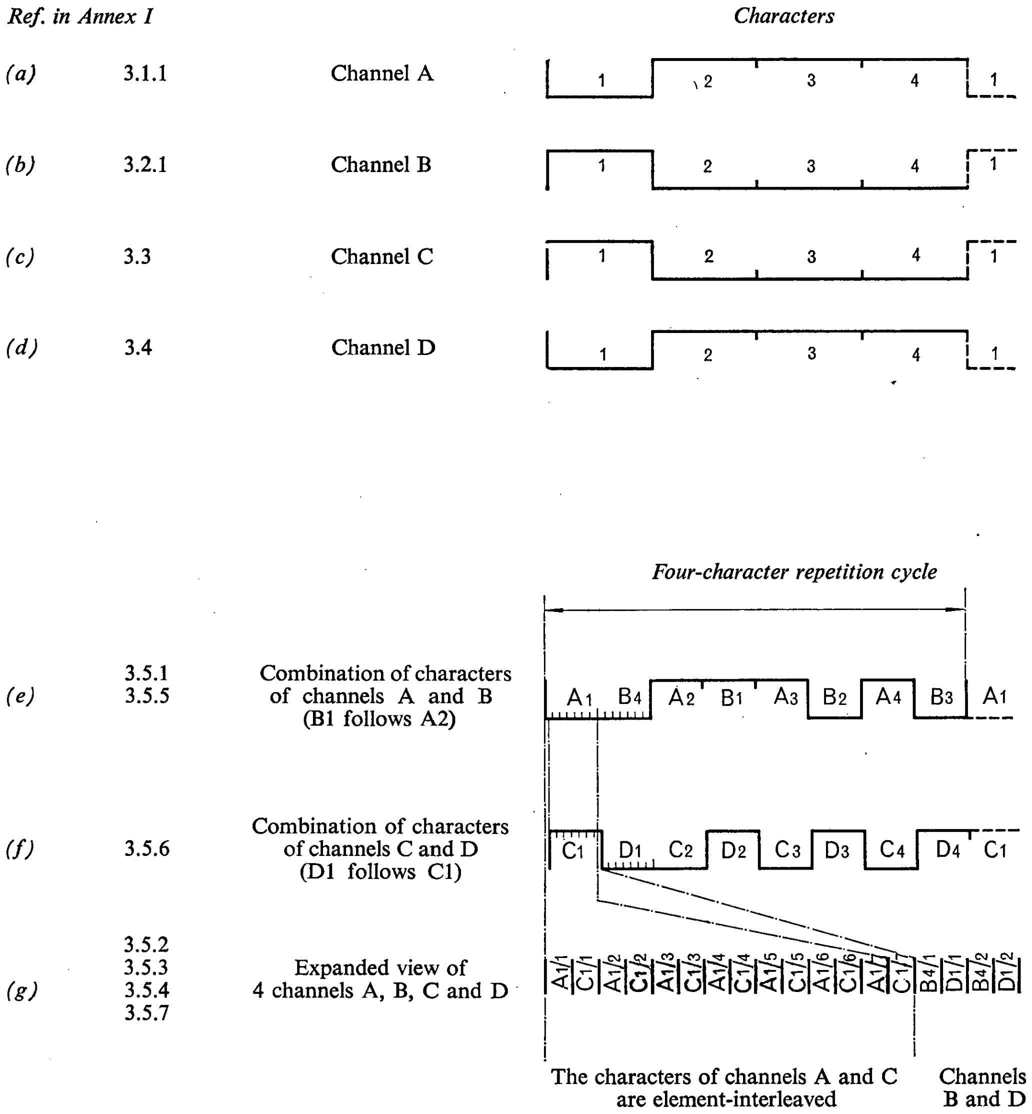

FIGURE 1

Channel arrangement for a four-character repetition cycle

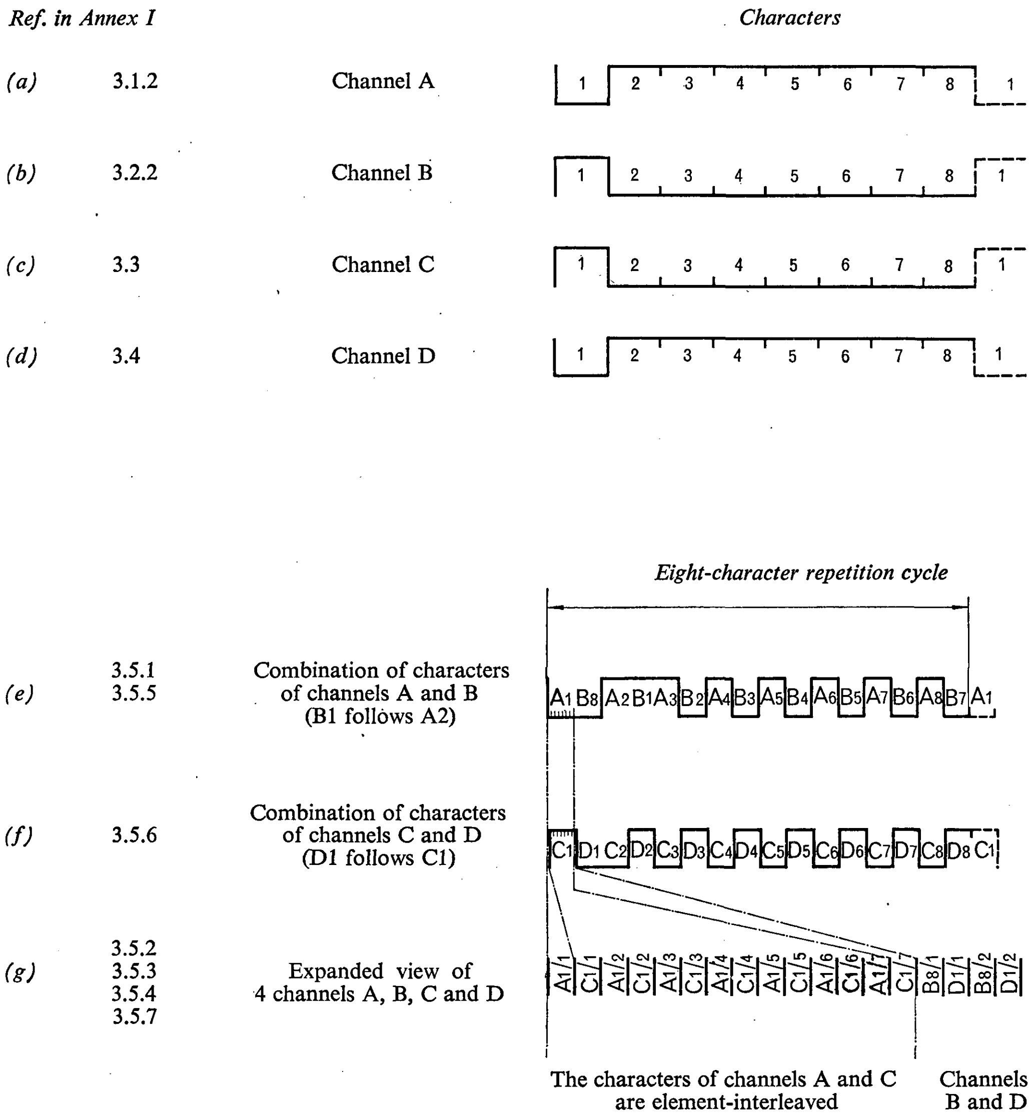

FIGURE 2

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
(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

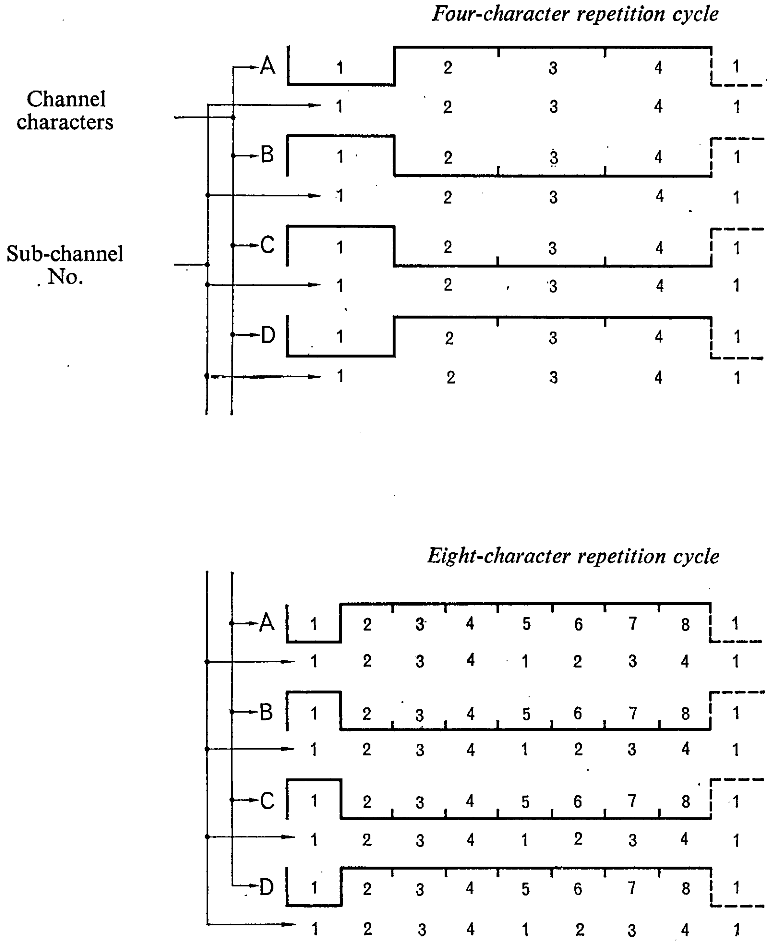

FIGURE 3
Sub-channelling arrangements for a four- and an eight-character repetition cycle

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" (Part 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

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_0,
frequency corresponding to black	f_0 – 400 Hz,
frequency corresponding to white	f_0 + 400 Hz;

2.2 *LF (kilometric) circuits*

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;

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

RECOMMENDATION 344-2

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

The C.C.I.R., (1948 – 1953 – 1956 – 1959 – 1963 – 1966 – 1970)

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.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;

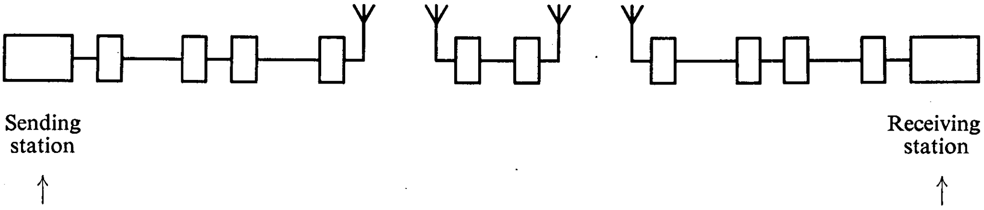
(The frequency 1500 Hz is also used for the phasing signal);

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

centre frequency (corresponding to the assigned frequency)	f_0,
frequency corresponding to white	f_0 – 400 Hz,
frequency corresponding to black	f_0 + 400 Hz;

(The frequency f_0 – 400 Hz is also used for the phasing signal);

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	2	8	2	2

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

16	2	2	16	2	16	2	2

FIGURE 1

If it is assumed that these deviations are distributed at random and if we take the standard deviation, we shall obtain the values 15 and 28 Hz respectively, which are not harmful for satisfactory reception, since C.C.I.T.T. Recommendation T.1 admits a maximum deviation of 32 Hz;

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

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.

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-stop 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 342-2)

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 346-1

FOUR-FREQUENCY DIPLEX SYSTEMS

(Question 8/3)

The C.C.I.R., (1956 - 1959 - 1963 - 1970)

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.

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

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

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

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;

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;

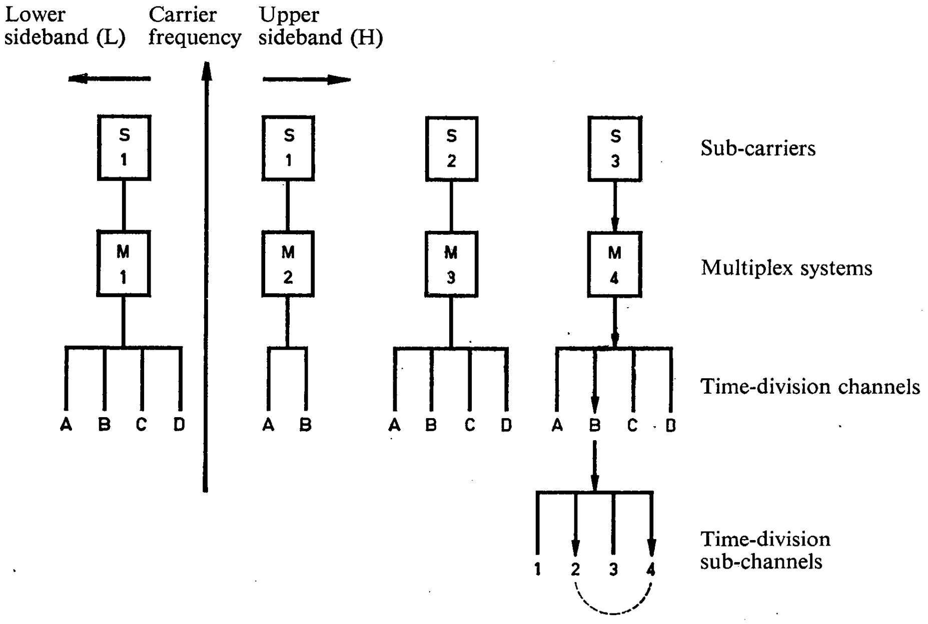
where channel B of the time-division system is sub-divided and sub-channel 2 is in use, the designation would be U3TB2;

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, channel and sub-channel 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 436-1

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

(Study Programme 17A-1/3)

The C.C.I.R., (1966 – 1970)

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 multi-channel 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: ±42·5 Hz or ±40 Hz)

Channel position	Central frequency (Hz)	Channel position	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

RECOMMENDATION 456

DATA TRANSMISSION AT 1200/600 BITS/S OVER HF CIRCUITS WHEN USING MULTI-CHANNEL VOICE-FREQUENCY TELEGRAPH SYSTEMS AND FREQUENCY-SHIFT KEYING

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

CONSIDERING

(a) that the effects of the random variations and disturbances in the HF propagation medium, in particular the effects of multipath distortion, in general preclude the use of serial transmission of binary data at rates of 1200 or 600 bits/s;

(b) that voice-frequency multi-channel frequency-shift systems that operate synchronously at a modulation rate of approximately 100 bauds are in widespread use over HF circuits;

(c) that such systems in effect provide an aggregate capacity of up to 1500 bits/s;

(d) that such systems, therefore, are suitable, and in fact are being used for data transmission at the standard data rates of 1200 and 600 bits/s;

(e) that the presence of multiplexer and demultiplexer or of land lines in the complete circuit may introduce envelope delay distortion, this distortion being most severe for the lowest and highest channels of a multi-channel voice-frequency frequency-shift system;

UNANIMOUSLY RECOMMENDS

1. that for data transmission at binary data rates of 1200 or 600 bits/s using frequency-division multiplex frequency-shift systems, the system described in the Annex be preferred;

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* See C.C.I.T.T. Recommendation R.70 bis.

Note. — By agreement between Administrations, the use of systems with a different number of channels and other channel spacings and modulation rates, for data transmission at 1200/600 bits/s, is allowed.

2. that channel spacing and central frequencies of the channels of the frequency-shift system should be in accordance with Table I of Recommendation 436-1;

3. that channels 3 to 14 inclusive of Table I of Recommendation 436-1 should be used for the transmission of the data.

ANNEX

1. Description of system

To avoid excessive multipath distortion, which would result when higher speed binary data streams are directly transmitted in serial form, the incoming-bit stream is converted into a number of relatively low-speed streams, which are transmitted simultaneously in parallel and recombined into a single serial data output at the receiving terminal.

In this way, the modulation rate of the channels transmitted over the HF circuit can be kept to an acceptable value.

A block diagram of the 1200 bits/s system is shown in Fig. 1.

2. Serial-to-parallel converter, transmission at 1200 bits/s

At the transmit side, the 1200 bits/s incoming-data stream is fed to a 12-bit shift register. At 12-bit intervals (i.e. at 10 ms intervals) the content of this register is transferred in parallel to a 12-bit storage register, the output of which is connected to 12 parallel channels of the multi-channel frequency-shift system.

Bit synchronization for the shift register may be:

2.1 extracted from the transitions of the data stream, provided the data stream is not expected to have excessive intervals during which no transitions occur (i.e. steady "1", or steady "0" condition);

2.2 obtained from a bit synchronizing signal from the data source, if available;

2.3 generated by an internal clock, in which case a synchronizing output is fed back to the data source.

The parallel transfer pulses are obtained from the bit synchronizing signal through a digital division process. If required, this frame synchronizing information may be transmitted over an additional channel of the frequency-shift system.

3. Channel arrangement, transmission at 1200 bits/s

The 12 channels of the frequency-shift system used for the transmission of the data information, each operating at a modulation rate of 100 bauds, shall be channels 3 to 14 inclusive of Table I of Recommendation 436-1; with channel 3 corresponding to the first (in time) bit of each 12-bit sequence, channel 4 to the second bit of this sequence, and so forth. The frequency spectrum occupied by these channels is that portion of the voice frequency band which is least affected by envelope delay distortion caused by multiplexer and demultiplexer filters or by land lines which may be incorporated between the terminal sites and the HF transmitting and/or receiving sites.

4. Parallel-to-serial converter, transmission at 1200 bits/s

The parallel-to-serial converter at the receiving terminal shall be designed to perform the following functions:

4.1 to provide delay equalization for the 12 individual channels of the frequency-shift system;

4.2 to provide frame synchronization and bit synchronization by means of extracting synchronization information from the data channels (or from the additional frame synchronizing channel, if this is used);

4.3 to sample the outputs of the 12 data channels, store the sampled data in a 12-bit storage register, transfer the stored data to a 12-bit shift register once per frame interval (10 ms) and read out the data in serial form.

A bit synchronizing output terminal shall be provided for synchronization of associated data equipment which may require a separate synchronizing signal.

5. Data transmission at 600 bits/s

For data transmission at 600 bits/s the following modes of operation are optional:

5.1 the use of 6 instead of 12 channels of the frequency-shift system;

5.2 the use of 12 channels of the frequency-shift system with dualling of channels to provide in-band frequency diversity;

5.3 the use of 12 channels of the frequency-shift system and reducing the channel modulation rate from 100 bauds to 50 bauds;

5.4 the use of 12 channels of the frequency-shift system and applying binary coding techniques to provide error correction, error detection or combined error correction/detection.

The option of § 5.1 enables two independent data streams at 600 bits/s to be transmitted in a single 3 kHz voice band. The options of §§ 5.2 and 5.3 provide improved performance (i.e., lower error rate) with little or no additional equipment required, but at the cost of increased bandwidth. Where lowest error rate is required, the use of redundant coding (which may include time-diversity methods) of the option of § 5.4 is preferred.

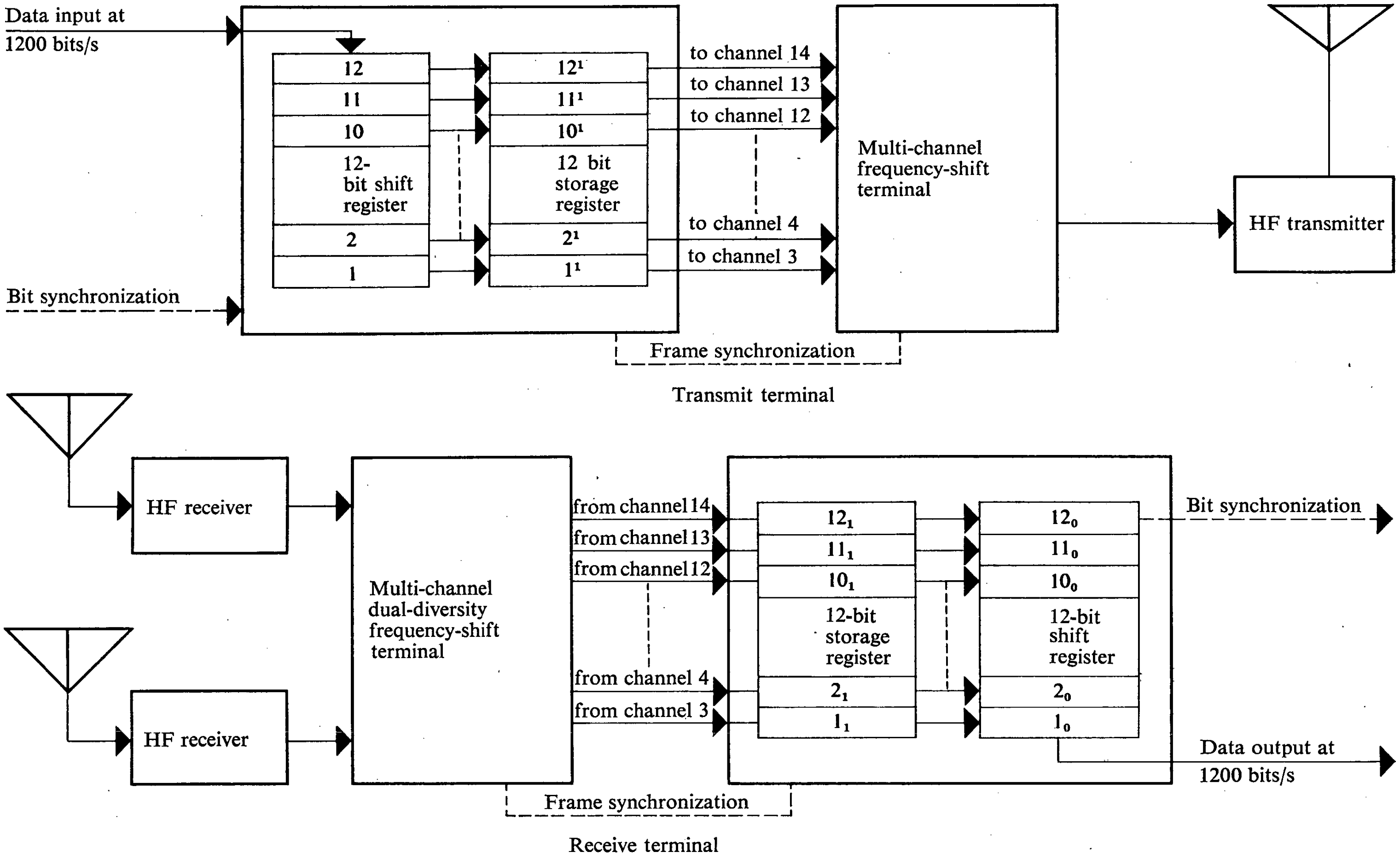

FIGURE 1

Data transmission system operating at 1200 bits/s

3C: *Reports*

REPORT 19-1*

VOICE-FREQUENCY TELEGRAPHY OVER HF RADIO CIRCUITS

(Study Programme 17A-1/3)

(1953 - 1966)

In principle, the voice-frequency telegraph systems described in 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 resistant to noise, but slightly more resistant 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.

REPORT 42-2*

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

(Study Programme 17A-1/3)

(1953 - 1956 - 1963 - 1966 - 1970)

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.

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* This Report was adopted unanimously.

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 positions	Central frequency (Hz)	Channel positions	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

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-1/3)

(1959 - 1963)

1. Study Programme 1A-1/3 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.

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* See C.C.I.T.T. Recommendation R.70 bis.

** This Report was adopted unanimously.

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:

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

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

$$P_e = \tfrac{1}{2}\operatorname{erfc}(\alpha R)^{\frac{1}{2}};$$

— for phase-reversal modulation $\alpha_1 = 1$;

— for frequency-shift keying with two orthogonal signals $\alpha_2 = \frac{1}{2}$;

— for amplitude keying (on-off signals) too, $\alpha_3 = \frac{1}{2}$.

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 $\alpha_2 = \frac{1}{2}$ (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] $\alpha_3 = \frac{1}{2}$.

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:

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

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:

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

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 Figs. 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: $P_c \approx 5P$;
- 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: $P_c \approx 34P_e$.

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:

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

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:

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

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:

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

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:

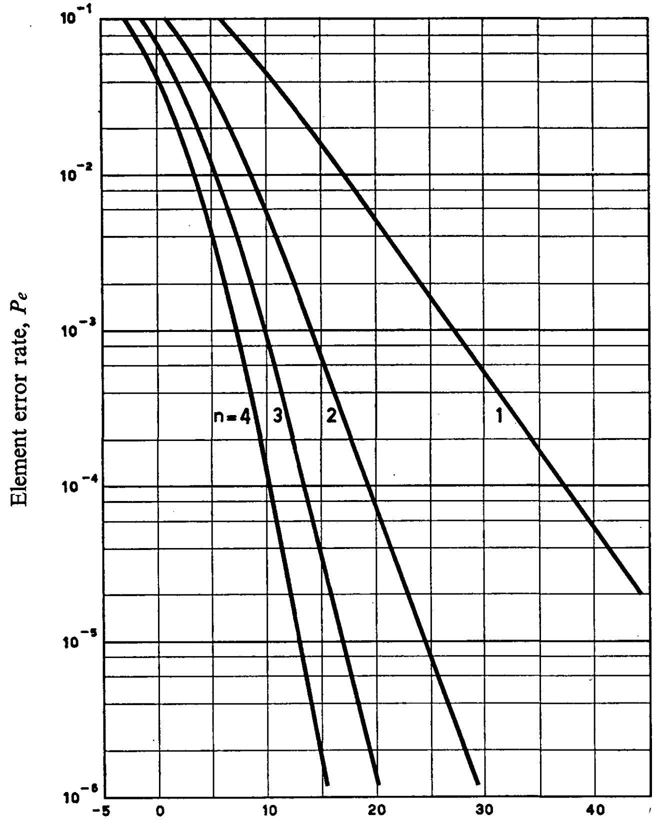
$$(D_q)^q = [2^q.q!(q-1)!/(2q-1)!]\ \sum\ (a_k/b_k{}^q)$$

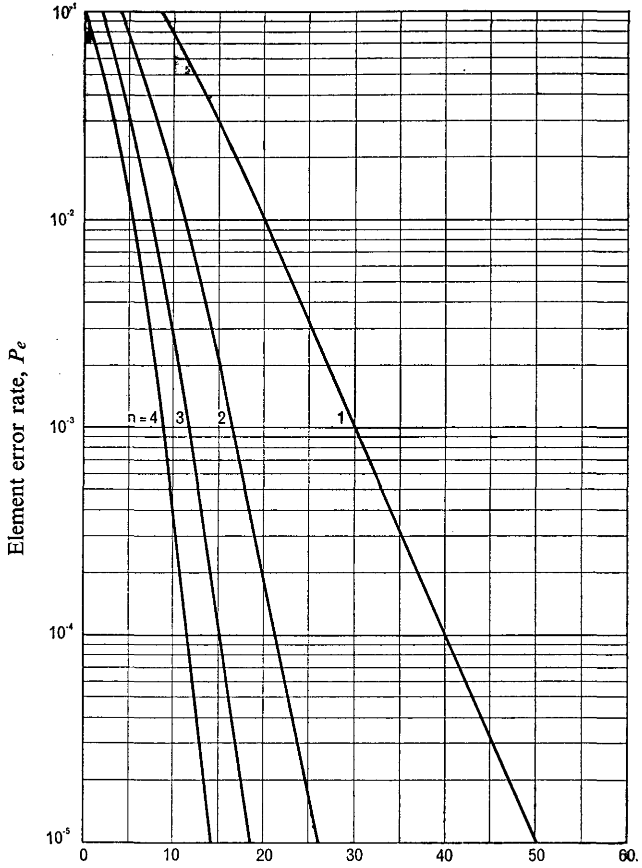
For other forms of the function $g\ (R)$, similar calculations can be performed.

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

FIGURE 2
Non-coherent reception

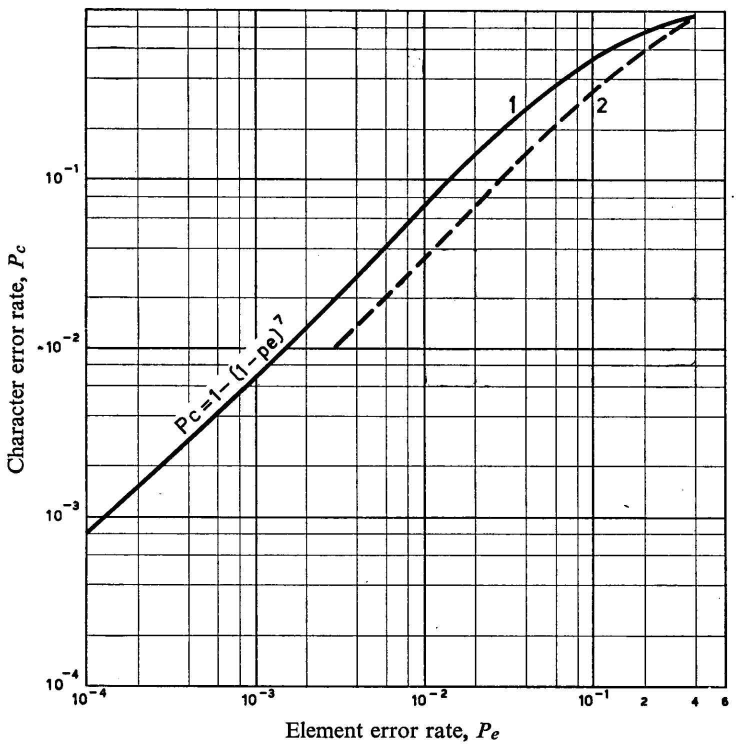


FIGURE 3

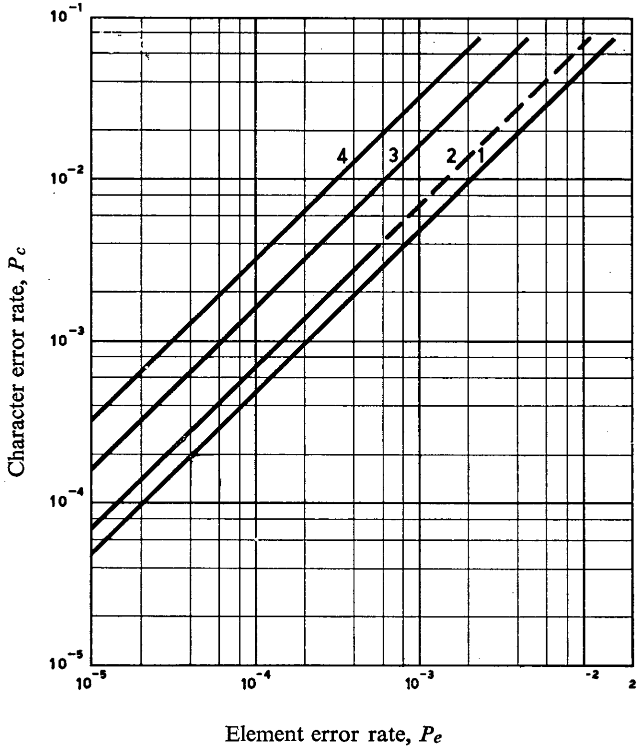


FIGURE 4

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 197-2*

FACTORS AFFECTING THE QUALITY OF PERFORMANCE OF COMPLETE SYSTEMS IN THE FIXED SERVICE

(Study Programme 1A-1/3)

(1963 – 1966 – 1970)

1. Urgent need for information

The attention of Administrations is drawn to the urgent need for the information requested in Study Programme 1A-1/3, for several classes of emission. As requested in the Annex to Study Programme 1A-1/3, 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.

Study Group 3 also needs the information to complete Recommendations 240-1, 339-2 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 efficiency, v, i.e. the probability of a correct character being printed and the attendant probability p, of a character error being printed as the result of a transposition [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.

The dependence of p on v, as measured in narrow-band channels using frequency-shift keying, is shown in Figs. 1 and 2 for different receiving arrangements. There the impurity, which is the probability (p/v) of observing a character error in the printed copy at the receiving end, is displayed as a function of v. So, if the circuit efficiency is known, the number of printed character errors can be predicted.

Fig. 1 shows that, in terms of impurity, with flat fading the performance of reception without diversity is inferior to that of diversity reception. As fading simultaneously affects both mark and space frequencies, diversity reception will favour the branch with the stronger signal thus improving both the purity and efficiency of reception.

Fig. 2 shows the behaviour with selective fading. Here the reverse is observed. Diversity reception enlarges the impurity to be expected for a certain value of v. This means that, though the circuit efficiency is increased by diversity reception, the impurity as a function of v will not fall off as much as with reception without diversity.

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* This Report was adopted unanimously.

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 of such triplets, the envelope contour has been calculated in 24 points, and also the harmonics up to the eleventh [3, 4 and 5].

4. Error rates on long distance HF communications

On links operating in band 7 (HF), transmission errors are, as a rule, not distributed stochastically in time, but periods with a high error-density (error bursts) alternate with periods of low error-density. Error bursts occur when the comparatively narrow transmission channel (e.g. for 100 bauds) is affected by selective fading and thus, the signal-to-noise ratio temporarily falls to, or even below a certain critical limit. Consequently the fading distribution allows conclusions to be drawn as to the duration and frequency of the error bursts to be expected [6]. The duration of a fading period is the time during which the receiving amplitude falls below a certain level relative to the mean receiving level.

According to [6] the duration of fading and its frequency may differ widely. Short-term fades are much more frequent than long-term fades. In Fig. 3, the number of fades is given as a function of the signal level for various circuits. For a fading level of 10 dB below the median level, there were about eight fades per minute on the New York/Frankfurt-am-Main radio link. Only 1% of all fades on this link lasted longer than 1 s, whereas half the fades exceeded 200 ms (Fig. 4). This leads to the conclusion that the time between two successive fades, with a low concentration of errors, is, as a rule, several times longer than the fading period.

Experimental results on long distance radiocommunications (2500-6000 km) in the west-east direction in the U.S.S.R. have shown that the error 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 [7, 8, 9], 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}).

5. Diversity reception and mutual signal correlation ratio

Experiments carried out in the U.S.S.R. have shown that the signal correlation ratio R (300 m distance between the antennae) depends on the path distance and on the relation f_{op}/MUF, where f_{op} is the operating frequency [10].

According to these experiments, the effectiveness of diversity reception decreases greatly when $R > 0{\cdot}6$. For path lengths up to 1500 km the probability of $R > 0{\cdot}6$ comes to 18% and for path lengths from 1500 to 3000 km this probability reaches 31%.

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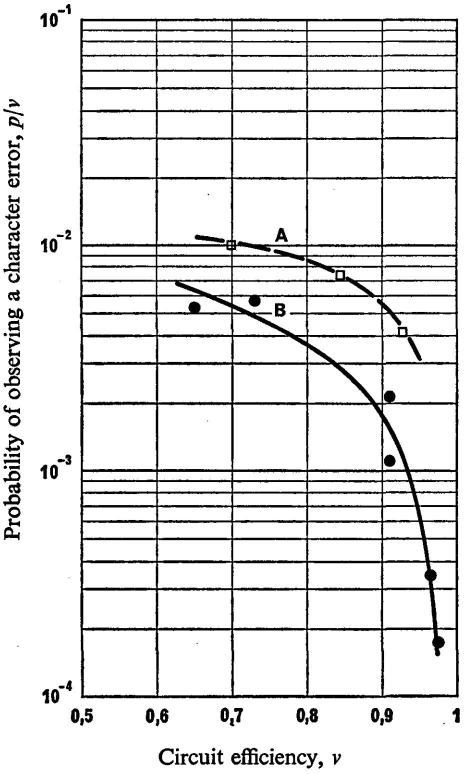

FIGURE 1

Probability of a character error (p/v) as a function of circuit efficiency, v, for flat fading

Curve A: without diversity
Curve B: with dual diversity

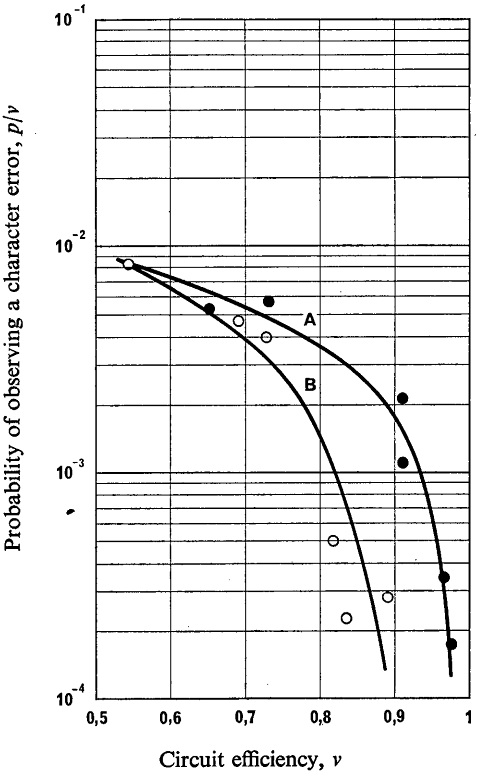

FIGURE 2

Probability of a character error (p/v) as a function of circuit efficiency, v, for selective fading

Curve A: without diversity
Curve B: with dual diversity, frequency or space

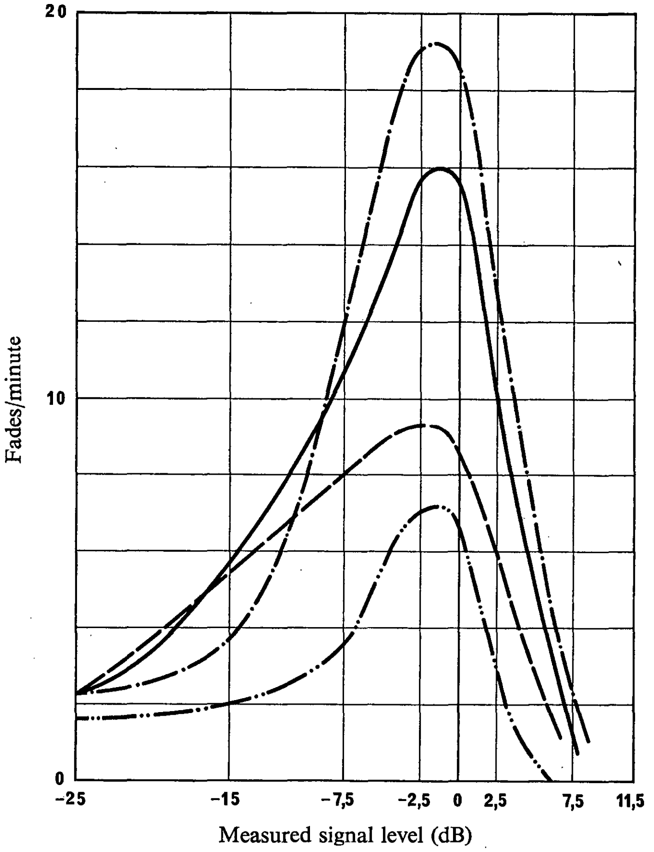

FIGURE 3

Number of fades per minute as a function of the signal level for various circuits (reception in Frankfurt)

—·—·— New York

— — — Seoul

——— Buenos Aires

—··—··— Ankara/Cairo for September, 1961

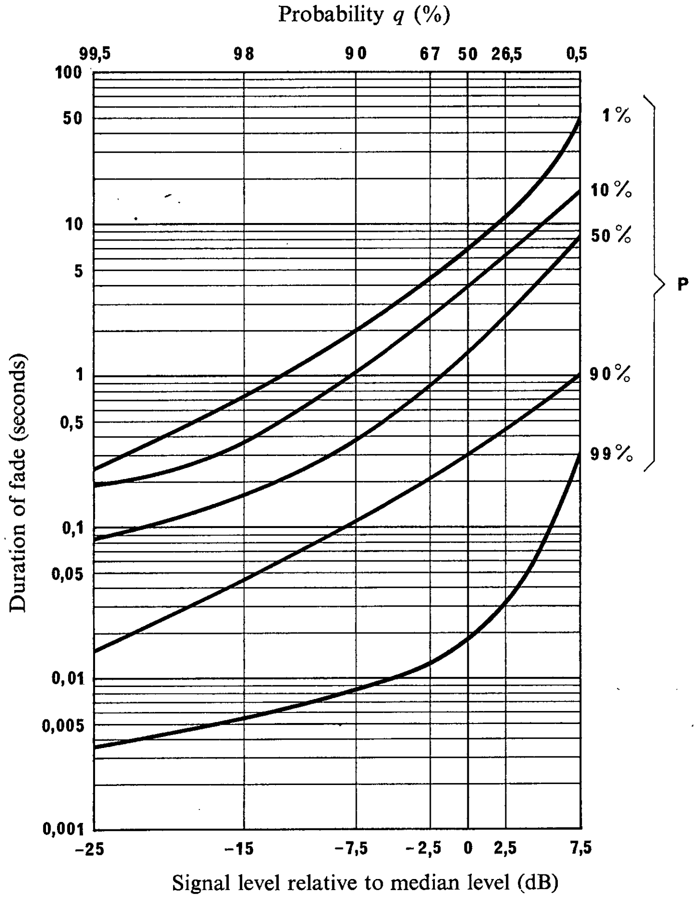

FIGURE 4

Duration of fades as a function of the level of the test signal

Circuit: New York – Frankfurt-on-Main; 14 September, 1961; 1100 h Central European Time; frequency 13·79 MHz.

The figures on the right-hand side of the curves represent the percentage p of the number of fades for which a given duration of fade is exceeded. The measured values of signal levels are shown, together with the probability q that these levels will be exceeded.

REPORT 198*

VOICE-FREQUENCY (CARRIER) TELEGRAPHY ON RADIO CIRCUITS

(Study Programme 17A-1/3)

(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 351-1).

2. Isochronous telegraph distortion

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

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.

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* This Report was adopted unanimously.

REPORT 201-2*

REMOTE CONTROL SIGNALS FOR FACSIMILE TRANSMISSIONS

(1963 – 1966 – 1970)

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.R. Recommendation 343-1).

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 C.C.I.T.T. Recommendation T.4 (White Book, Vol. VII).

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.

REPORT 345-1*

PERFORMANCE OF TELEGRAPH SYSTEMS ON HF RADIO CIRCUITS

(Study Programme 17A-1/3)

(1966 – 1970)

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 hertz 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 of 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 normalized 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 multipath 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, multipath 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 undetected 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 automatic retransmission 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 *B1* but for the sake of clarity only a single curve is shown; system *B2* has been omitted since its performance at 100 bauds is not better overall than that of *B1* 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*, *B1* and *B2* and, if fading conditions ranging between the extremes considered are assumed, that *B1* 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, bandwidth 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 I 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 I

Performance of a practical 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 bandwidth, to give stated efficiency (dB)		
		50%	70%	90%
A *B1*	8 16	2 to 3 6 to 7	3·5 to 5·5 8·5 to 10	6·5 to 9 12 to 14

2.5 *Characteristics of system B*

It will be observed from Figs. 2 and 3 that the system *B1* performance tends to approach a specific minimum value for each condition rather than progress to zero with uniform slope as does system *A*. Further work in the United Kingdom [5] has thrown fresh light on this phenomenon, known as "bottoming", observed on real communication channels using frequency modulation. It is there shown that when two approximately equal signal components reach the receiver by direct and delayed paths they may combine with any relative phase. When the components are in phase opposition then large and rapid phase alternations can occur, sufficient in some cases to displace transitions by more than the differential multipath delay.

This phenomenon is not by itself, however, sufficient to account for the residual element error rate experienced. Restriction by the channel filters of the higher order sidebands produced in the frequency-modulation process inevitably causes some amplitude modulation which has a fundamental frequency twice that of the frequency modulation. This has the effect of prolonging the period over which the resultant signal phaser is undergoing rapid changes of phase. As an example the frequency displacement due to this rapid change can be as high as 100 Hz over a period of 10 ms, sufficient to cause a reversal of polarity on a channel having a deviation of 40 Hz.

Analysis of this phenomenon confirmed by measurements over the fading simulator of § 2.2 have shown the residual element error rate on such a system to be:

- proportional to the square of the path time difference of a two equal mode propagation path,
- a function of the deviation,
- an inverse function of the bandwidth of the channel filter,
- sensibly independent of the fading rate,
- not greatly reduced by space-diversity operation as simulated by two paths subject to uncorrelated fading,
- largely made up of groups of errors of the same polarity.

Other work in Japan [6] has given results almost the same as those stated above. In this, mathematical analysis and operational observations were made on the system *B* operated between Tokyo and San Francisco.

Both of them showed that:

- multipath distortion is frequently observed on HF radio circuits even at times of favourable propagation conditions and when the received signal is strong;
- when the bandwidth of the channel filter is not wide enough to pass the essential sidebands, the waveform of the demodulated signal is severely distorted, causing intolerable errors.

In conclusion, it has been suggested that the following methods should be used to reduce error rate:

- to operate at a higher frequency, near the MUF, despite the fact that the receiving signal is not as strong as at the optimum frequency;
- to use the optimum modulation index ($m =$ total frequency shift in Hz/modulation rate in bauds) which concentrates the distribution of higher level essential sidebands close to the centre frequency (usually $m \approx 0{\cdot}8$ is recommended) for the transmission of the signal waveform;
- for high-speed transmission (more than 100 bauds), to divide the incoming signal into lower speed signals (maximum of 100 bauds) for transmission over the radio path, by using a serial-to-parallel converter at the transmitting end and to recombine them into a single high-speed signal using a parallel-to-serial converter at the receiving end.

2.6 *Further tests under conditions of multipath distortion*

Results obtained from tests on two channels of system *B1*, used in frequency diversity, that were provided with signals from a fading simulator, seem to indicate that system *B1* will 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. The artificial fading used during the tests was selective fading, produced by the interference of five equally active paths, differing in propagation time from one to the other by approximately equal amounts such that an overall difference of 2 ms was achieved. The two diversity branches of the receiver were provided with signals having uncorrelated fading patterns.

3. Comparison between 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 utilizing 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 single-sideband receiver and fed to both the dual-diversity two-tone and FM-VFT channel equipment.

Synchronous electronic regenerators were used to eliminate the distortion from channels on both 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 number 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 station logs, radio condition 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 [7] 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 these figures, 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 frequency-modulation 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 frequency-modulation 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.

However, if the major traffic load is 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, adopted in C.C.I.T.T. Recommendation U.23 were used, i.e. automatic "clearing" of these circuits whenever 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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* 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.

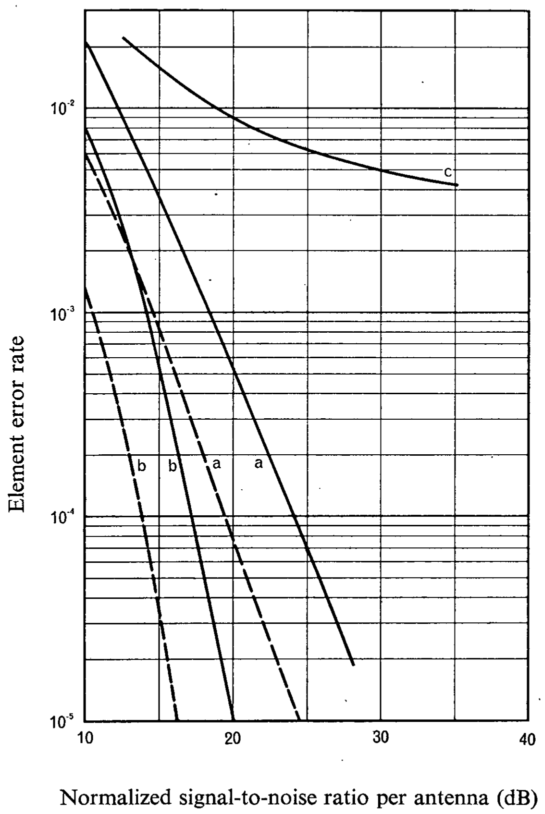


FIGURE 1

System A. Dual space-diversity reception

----- Reference system

——— System *A*

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

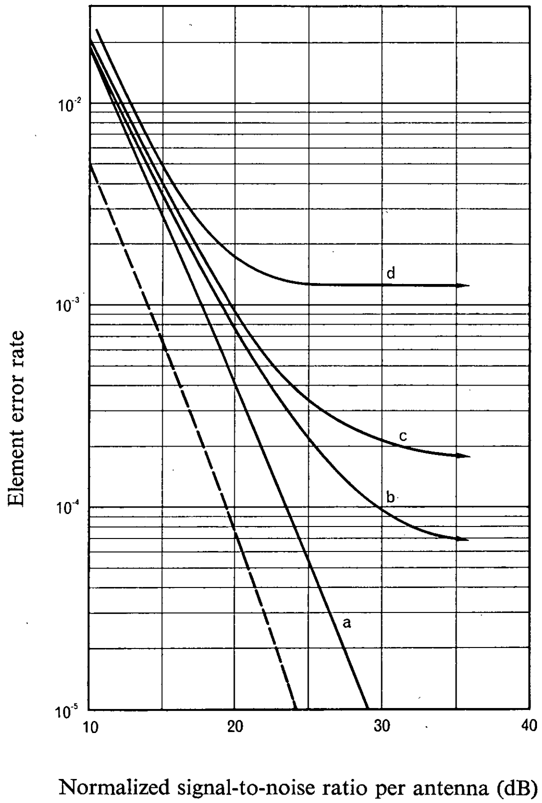


FIGURE 2

System B1. Dual space-diversity reception

----- 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 per min

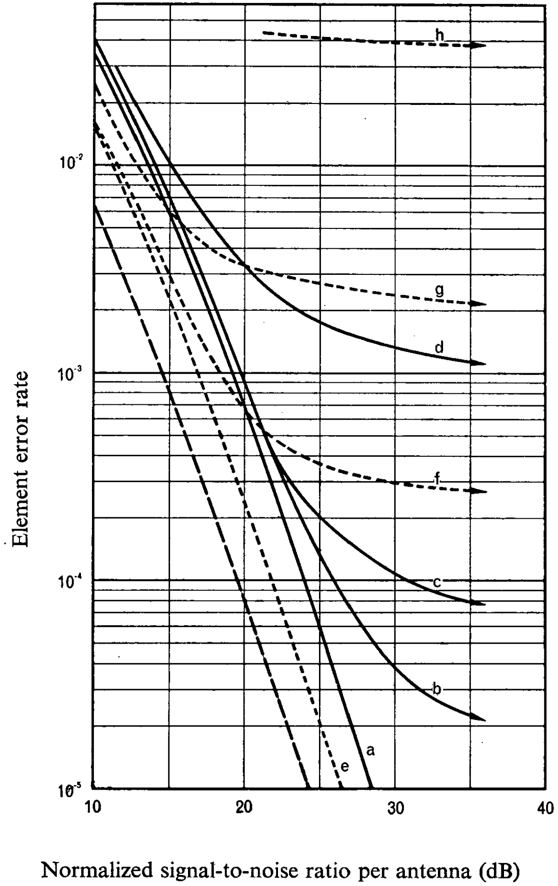


FIGURE 3
System B2. Dual space-diversity reception

— — — — 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

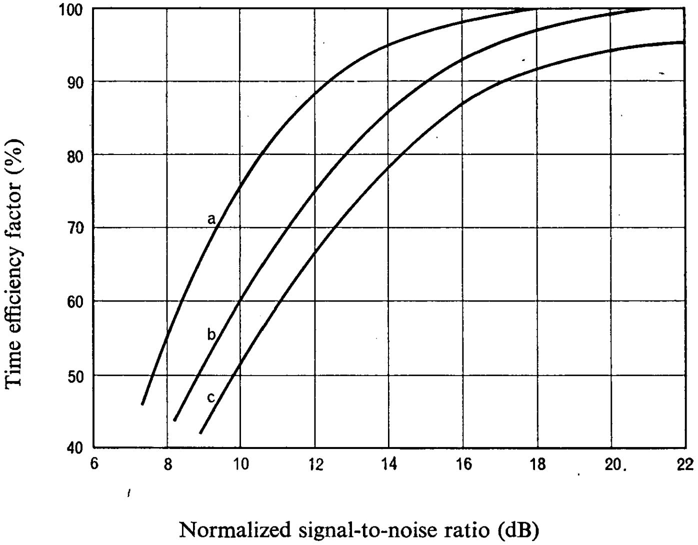


FIGURE 4
Time efficiency factor

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

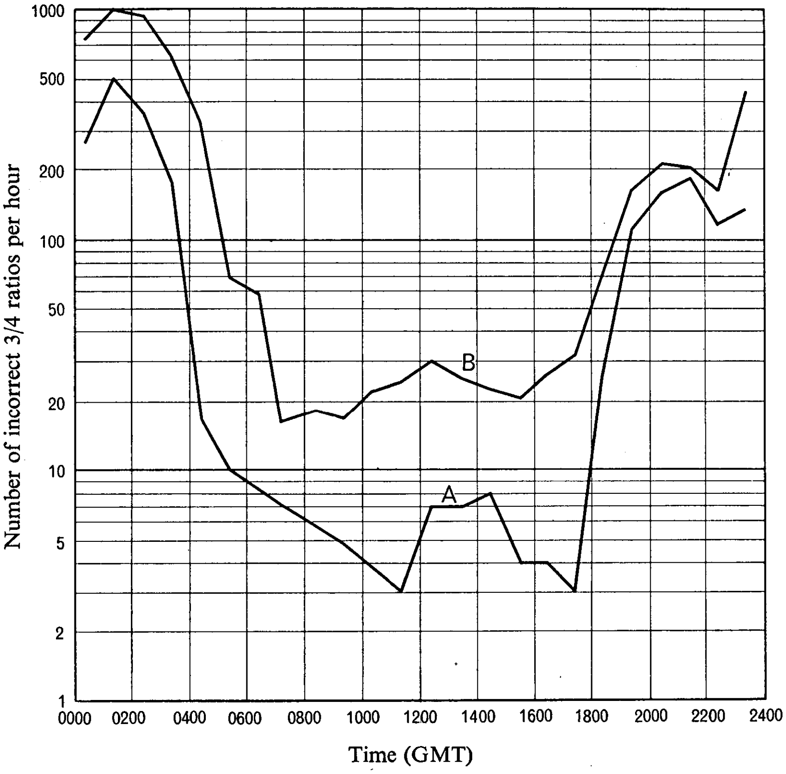


FIGURE 5

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)

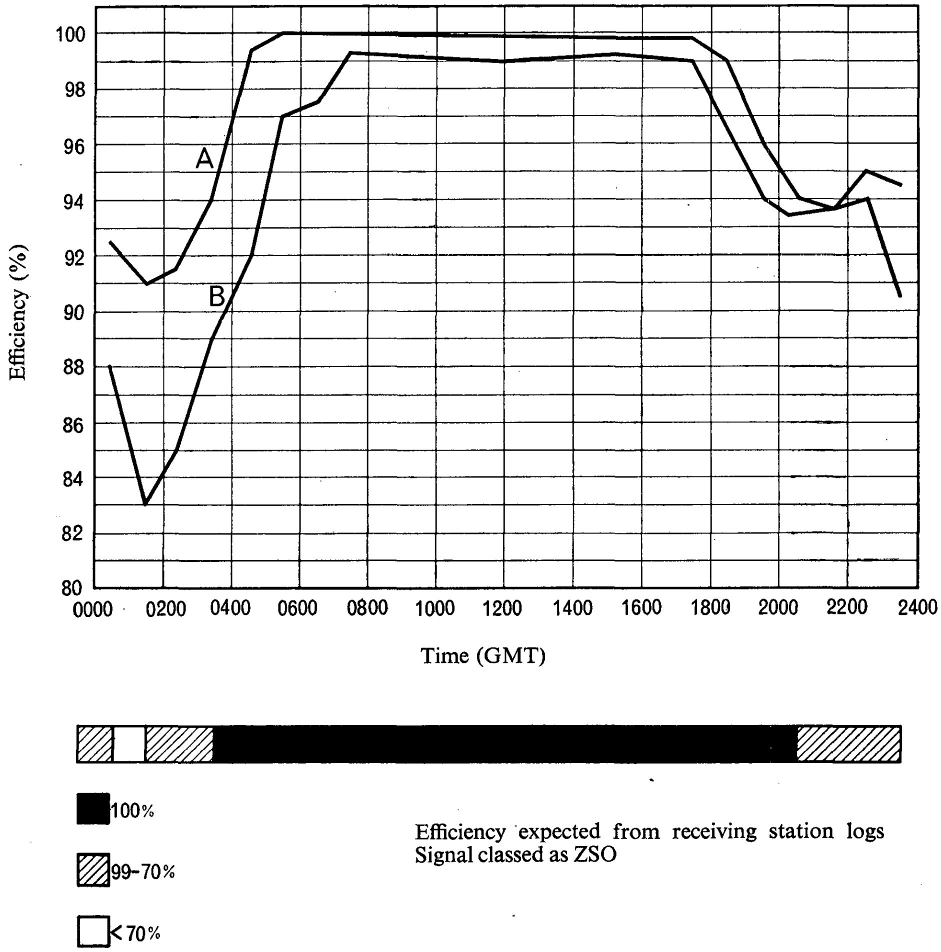
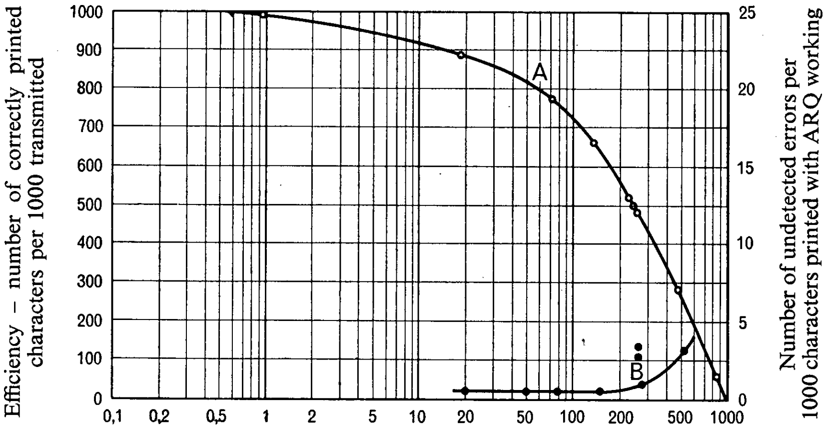


FIGURE 6

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-1/3)

(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.

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* 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].

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-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, United States of America, 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 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 changeovers. This problem was minimized whenever possible by frequency dualling 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 bauds) 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 in automatic 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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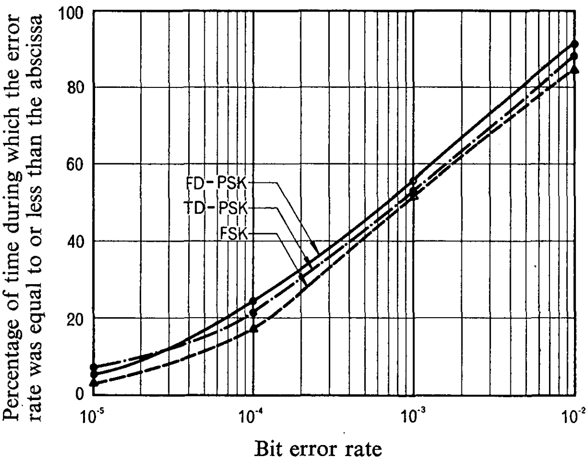

Figure 1

Cumulative performance curves

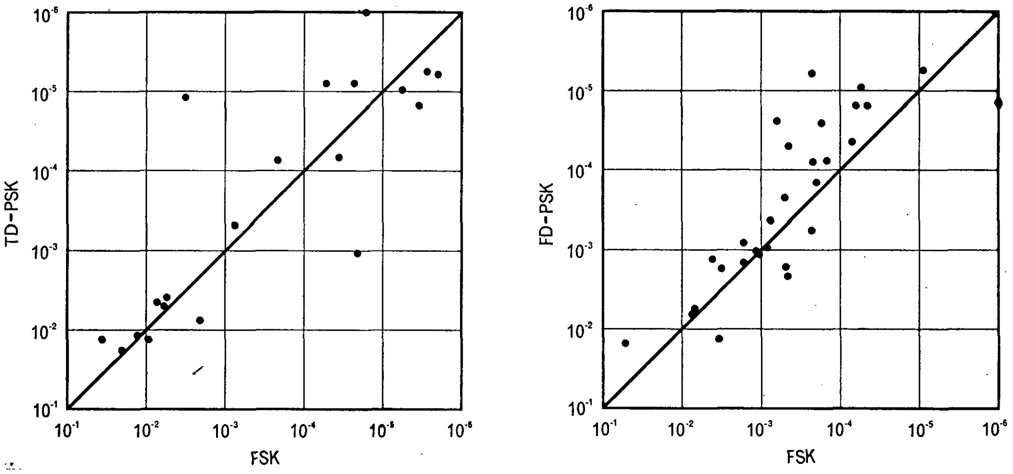

Figure 2

Scatter diagrams of error rates for parallel runs

REPORT 347*

VOICE-FREQUENCY TELEGRAPHY OVER RADIO CIRCUITS

(Study Programme 17A-1/3)

(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 ±35 Hz as in the Table of Report 42-2. 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.

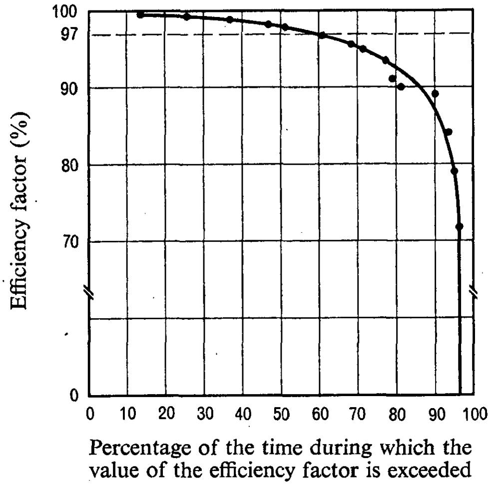

FIGURE 1

Distribution of efficiency factor in a 100 baud ARQ system with a 120 Hz central frequency spacing

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* This Report was adopted unanimously.

REPORT 348-1*

SINGLE-CHANNEL SIMPLEX ARQ TELEGRAPH SYSTEM

(Study Programme 1A-1/3)

(1966)

1. Introduction

1.1 Study Programme 1A-1/3 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.

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.*

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* This Report was adopted unanimously.

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 mutilated 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 I

Table of code conversion

	International Alphabet No. 2	7-unit code	Emitted signal (¹) (Frequency condition)
A	ZZAAA	ZZZAAAZ	BBBYYYB
B	ZAAZZ	AZAAZZZ	YBYYBBB
C	AZZZA	ZAZZZAA	BYBBBYY
D	ZAAZA	ZZAAZAZ	BBYYBYB
E	ZAAAA	AZZAZAZ	YBBYBYB
F	ZAZZA	ZZAZZAA	BBYBBYY
G	AZAZZ	ZAZAZZA	BYBYBBY
H	AAZAZ	ZAAZAZZ	BYYBYBB
I	AZZAA	ZAZZAAZ	BYBBYYB
J	ZZAZA	ZZZAZAA	BBBYBYY
K	ZZZZA	AZZZZAA	YBBBBYY
L	AZAAZ	ZAZAAZZ	BYBYYBB
M	AAZZZ	ZAAZZZA	BYYBBBY
N	AAZZA	ZAAZZAZ	BYYBBYB
O	AAAZZ	ZAAAZZZ	BYYYBBB
P	AZZAZ	ZAZZAZA	BYBBYBY
Q	ZZZAZ	AZZZAZA	YBBBYBY
R	AZAZA	ZAZAZAZ	BYBYBYB
S	ZAZAA	ZZAZAAZ	BBYBYYB
T	AAAAZ	AAZAZZZ	YYBYBBB
U	ZZZAA	AZZZAAZ	YBBBYYB
V	AZZZZ	AAZZZZA	YYBBBBY
W	ZZAAZ	ZZZAAZA	BBBYYBY
X	ZAZZZ	AZAZZZA	YBYBBBY
Y	ZAZAZ	ZZAZAZA	BBYBYBY
Z	ZAAAZ	ZZAAAZZ	BBYYYBB
Carriage return	AAAZA	AAAZZZZ	YYYBBBB
Line feed	AZAAA	AAZZAZZ	YYBBYBB
Figure shift	ZZAZZ	AZZAZZA	YBBYBBY
Letter shift	ZZZZZ	AZAZZAZ	YBYBBYB
Space	AAZAA	AAZZZAZ	YYBBBYB
Unperforated tape	AAAAA	AZAZAZZ	YBYBYBB

Service information signals

Mode A (ARQ)	Emitted signal (¹)
Control signal 1	BYBYYBB
Control signal 2	YBYBYBB
Control signal 3	BYYBBYB
Idle signal β	BBYYBBY
Idle signal α	BBBBYYY
Signal repetition	YBBYYBB

(¹) The higher emitted frequency is designated by B and the lower by Y (see Recommendation 246-2, § 8).

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 349-1*

SINGLE-CHANNEL RADIOTELEGRAPH SYSTEMS EMPLOYING FORWARD ERROR CORRECTION

(Study Programme 18A/1)**

(1966 – 1970)

1. Introduction

Contributions by Administrations to the XIth Plenary Assembly, Oslo, 1966, provided 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 in this Report, as well as the pertinent Docs. III/107 and III/117, 1963 – 1966 and Doc. III/9 (United States of America), 1966 – 1969. More detailed tests, utilizing laboratory simulation, were reported in Docs. III/81 and III/91, 1966 – 1969, and are also summarized.

2. Summary and discussion of reported results

2.1 Docs. XIII/82 (United Kingdom) and XIII/120 (Norway), 1963 – 1966, 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 Telegraph Alphabet 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.

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* This Report was adopted unanimously.

** This Study Programme replaces Study Programme 5A/III.

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 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.

A further development of the system described above consists of element interleaving of blocks of 10 characters, providing 10 element (145 ms) error-burst correction capability.

2.2 Doc. III/107 (Netherlands), 1963 – 1966, 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 directly to the printer. If neither reception is found acceptable, a special "space" symbol is printed.

Furthermore, a third decision can be taken into account when it is not sufficiently sure whether a mark or space was received (zero-position marker). When this condition occurs, it also results in the printing of the special "space" symbol.

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.

This system may be viewed in either of two ways:

— 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;

— 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.

Systems performance measurements, utilizing laboratory simulation, have been made (see § 3.2).

2.3 The time-diversity system reported by Lyons [2, 3, 4] provides a burst error-correction capability for bursts up to 1·5 s, as well as having the capability of correcting most single and other multiple errors. It is particularly suitable for the reduction of errors due to time-variant distortion effects commonly experienced on HF radio circuits, such as impulsive or burst noise, sporadic interference and certain cases of selective fading due to multipath propagation.

The system utilizes two adjacent channels of a multi-channel voice-frequency frequency-shift system, each operating at a modulation rate of up to 100 bauds. One of the two channels transmits the information without delay (hereafter called the normal channel), while the other channel transmits the same information, but delayed in time by approximately 1·5 s (hereafter called the delayed channel). In addition, a parity bit is inserted after each nine information bits in the input bit stream. The information rate (bits/s) on the system is then equal to 0·9 times the modulation rate of either of the voice-frequency telegraph channels. The system is independent of input format and can be used equally well with character type transmission as with random digital input data.

Upon reception, both the normal and the delayed channel are examined for bit distortion (margin assessment) and, based on this assessment, either the normal or the delayed channel is selected as the primary channel. If, however, a parity error is found in a block in the primary channel, only that block is then taken from the other channel, provided it has no parity error.

Results obtained from a field trial of several weeks duration over a long-haul HF circuit using dual space diversity at the receiving end showed that for character error rates of approximately 1×10^{-2} on the normal channel without time diversity, the corresponding error rate of the time diversity system (measured simultaneously) was approximately 1×10^{-5}.

2.4 Doc. III/117 (United States of America), 1963 – 1966, 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:

2.4.1 a system using a (15,10) block code (i.e. 10 information bits and 5 check bits per block), interleaved to provide 2 s burst error correction capability. This system was tested at teletype speeds over an HF link [5], 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};

2.4.2 a system using an adaptive convolutional code (Gallager code) with maximum burst error-correction capability of 6 s. 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.

A test is reported whereby this system was compared with the use of frequency diversity. Analyzed 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 [6].

3. Systems performance measurements utilizing laboratory simulation

3.1 Doc. III/81 (United Kingdom), 1966 – 1969, presents a comparison between typical forward error correcting systems tested under simulated propagation conditions in band 7 (HF) [7]. The systems all accepted and delivered 50 baud start-stop teleprinter signals but used synchronous transmission in the radio path, the modulation rate of which is indicated in § 3.1.1 individually.

3.1.1 The systems tested were as follows:

System A, as described in § 2.1, with no element interleaving. Synchronous modulation rate 68·5 bauds.

System B, as system *A* but with blocks of 10 characters element-interleaved. Synchronous modulation rate 68·5 bauds.

System C. A half-rate, recurrent code similar to [8], but with two additional check elements per character to detect uncorrected errors and substitute error symbols, and internal dispersion giving 12 element (145 ms) error-burst correction. Synchronous modulation rate 83 bauds.

System D, as described in § 2.2 without third-decision detector (zero position marker). Synchronous modulation rate 100 bauds.

System D′, as system *D*, but with third-decision detector. Synchronous modulation rate 100 bauds.

System E. A half-rate diffuse convolutional code with threshold decoding giving 32 element (350 ms) error-burst correction [9, 10]. Synchronous modulation rate 90 bauds.

Reference system. Uncoded except for the addition of one element per character for character synchronization. Synchronous modulation rate 42·3 bauds.

3.1.2 *Test conditions*

3.1.2.1 *Modulation F1*, phase continuous, 170 Hz total frequency shift.

3.1.2.2 *Demodulation.* Two alternative methods of demodulation were employed:

- filter-assessor with filter bandwidths of 140 Hz (3 dB);
- limiter-discriminator with predetection filter bandwidth of 180 Hz (3 dB), except for system *D′*, which had a built-in limiter-discriminator with a predetection filter bandwidth of 500 Hz (3 dB).

3.1.2.3 *Digital test signal.* Repetitive pattern consisting of all the characters of International Telegraph Alphabet No. 2, except combination 32 (all space).

3.1.2.4 *Simulated propagation conditions.* Measurements were made with flat, Rayleigh distributed random fading and with selective fading produced by equal activity, independently-fading, two-path propagation having a path-time difference of 2 ms. Tests were made with quasi-random fading rates of 10 and 40 fades per minute. Additive Gaussian noise was used and the signal-to-noise ratio was normalized [11], but with respect to the nominal data transfer rate (50 bauds) instead of to the modulation rate in order to provide a more objective evaluation of the advantages of forward error correcting coding systems.

3.1.2.5 *Character error count.* Incorrectly printed characters (i.e. undetected character errors) and printed error symbols were counted as character errors.

3.1.2.6 *Test results.* Figs. 1 to 4 represent the results of the tests for dual space diversity and for single aerial reception. System *D′* was not tested with diversity reception.

3.2 Doc. III/91 (Netherlands), 1966 – 1969, presents performance measurements for two forward error correcting systems under simulated propagation conditions in band 7 (HF) [7]. Both systems accepted and delivered 50 baud start-stop teleprinter signals and used synchronous transmission in the radio path.

3.2.1 *The systems tested* were as described in § 2.2, one system with and the other without third-decision detector. Synchronous modulation rate for both was 100 bauds.

3.2.2 *Test conditions*

3.2.2.1 *Modulation F1*, phase continuous, 200 Hz total frequency shift.

3.2.2.2 *Demodulation* limiter-discriminator with predetection filter bandwidth of 500 Hz (3 dB). The third-decision detector, when used, was adjusted to 33% of peak detector output.

3.2.2.3 *Digital test signal.* The test signal consisted of repetitive transmission of signal *R* of Report 348-1.

3.2.2.4 *Simulated propagation conditions.* Measurements were made with flat, Rayleigh distributed random fading and with selective fading produced by equal amplitude, independently phase-varying, five-path propagation with time delays of 0·5 ms between successive paths. Tests were made with quasi-random fading rates of 10, 30 and 40 fades per minute. Additive Gaussian noise was used and the signal-to-noise ratio was normalized [11] to the modulation rate (100 bauds). Figs. 5 to 8 in this Report have been adjusted to a normalized S/N ratio with respect to the information transfer rate (50 bauds) to achieve conformity with § 3.1.

3.2.2.5 *Character error count.* Incorrectly printed characters (i.e. undetected character errors) and printed error symbols were counted as residual character errors (E_R). Undetected character errors were also counted separately (E_u).

3.2.2.6 *Test results.* Figs. 5 to 8 represent the results of the tests for single antenna reception.

3.3 *Discussion of results*

3.3.1 Selective fading characteristics corresponding to equal activity, independently fading, two-path propagation with a path-time difference of 2 ms and a fading rate of 10 fades/minute were chosen in the tests of § 3.1 as being representative of very unfavourable propagation conditions, and thus provide a lower bound on the performance that might be expected from the various systems tested.

The condition of flat, Rayleigh distributed random fading with a fading rate of 10 fades/minute represents rather favourable propagation conditions, but cannot be taken as an upper bound as all the forward error correcting systems gave a better performance with a fading rate of 40 fades/minute. This may be taken as an indication that a longer burst-error correction capability might be beneficial to cope with the lower fading rates.

3.3.2 Figs. 1 to 4 represent the results of the tests described in § 3.1. It was found that, under the particular test conditions described in § 3.1.2, the filter-assessor method of demodulation gave markedly superior results in the presence of selective fading. This can be accounted for by the distortion effects that arise from multipath propagation when using narrow predetection filter bandwidths with limiter-discriminator detection [12].

With the filter-assessor method of demodulation, all forward error correction systems tested gave an improvement over the reference system, the performance of individual systems being within 1 or 2 dB of another.

With the limiter-discriminator method of detection and under conditions of selective fading with a fade rate of 10 fades/minute, the individual performances of the different systems varied more widely. The performance of the reference system, under these conditions, was equal to or better than the performance of some of the forward error correcting systems. This may be ascribed to the lower modulation rate of the reference system, and the consequently lower distortion experienced.

With respect to the curves of system D', it must be remembered that the predetection bandwidth for this system was 500 Hz as compared to 180 Hz for all other systems with limiter-discriminator demodulation. The threshold of the third decision detector was set to approximately 50% of the peak detector output.

3.3.3 Selective fading characteristics corresponding to those produced by five equal amplitude, independently phase-varying, path components with incremental time delays of 0·5 ms were chosen in the tests of § 3.2 as being representative of fairly severe multipath conditions. Fading rates of 10, 30 and 40 fades/minute were used to evaluate the effectiveness of the forward error correcting methods, which have a fixed amount of burst error correction capability.

3.3.4 Figs. 5 to 8 represent the results of the tests described in § 3.2. Both the residual error rate (E_R) and the undetected error rate (E_u), see § 3.2.2.5, are shown in these figures.

Under all conditions, E_R improves with increasing fade rate, as would be expected from the fixed value of time delay between the first part and the second part of the (14 element) character.

Under flat fading conditions, E_R approaches E_u at very high S/N ratios, indicating that under these conditions most of the residual errors are undetected. Application of third decision detection shows a significant decrease in E_u for both fading rates, and thus a significant decrease in E_R at high S/N ratios.

Under selective fading conditions, E_R does not approach E_u at very high S/N ratios, and the results show that most of the residual errors are detected but uncorrected.

Application of third decision detection shows again a marked decrease in E_u, but in this case a slight increase in E_R, indicating an increase in detected but uncorrected errors.

3.4 Phasing time is an important aspect of the application of forward error correcting systems. Phasing time of the different systems under all test conditions was measured in the tests described in § 3.1. Systems *D* and *E* invariably phased in less than one second. The median times for systems *A*, *B* and *C* were of the order of 15 s. The phasing times observed in 99% of the tests of these three systems were less than 21, 47 and 25 s respectively. In conditions of very high error rate no system was able to achieve phase.

4. Conclusions

Performance of uncoded frequency-shift-keyed systems is, amongst others, dependent on multipath time delay spread and configuration (i.e. number and activity of individual paths), modulation index and predetection filter bandwidth in the case of limiter-discriminator detection.

For coded systems, fading rate also becomes an important factor as this has a significant influence on the time distribution of the errors.

Attention is drawn to the importance of standardizing test conditions, the parameters of ionospheric channel simulators and typical patterns of ionospheric behaviour to enable the comparison between laboratory results to be improved (see also Question 21/3).

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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 per 1000 characters	2·27 per 1000 characters	0·055 per 1000 characters	2·33 per 1000 characters
XIII/82	Ship to shore, single-sideband transmission, space-diversity reception					0·84 per 1000 characters
XIII/120	Ship to shore, double-sideband transmission, space-diversity reception (¹) (²)	287 776		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 ¼ of nominal power for technical reasons.

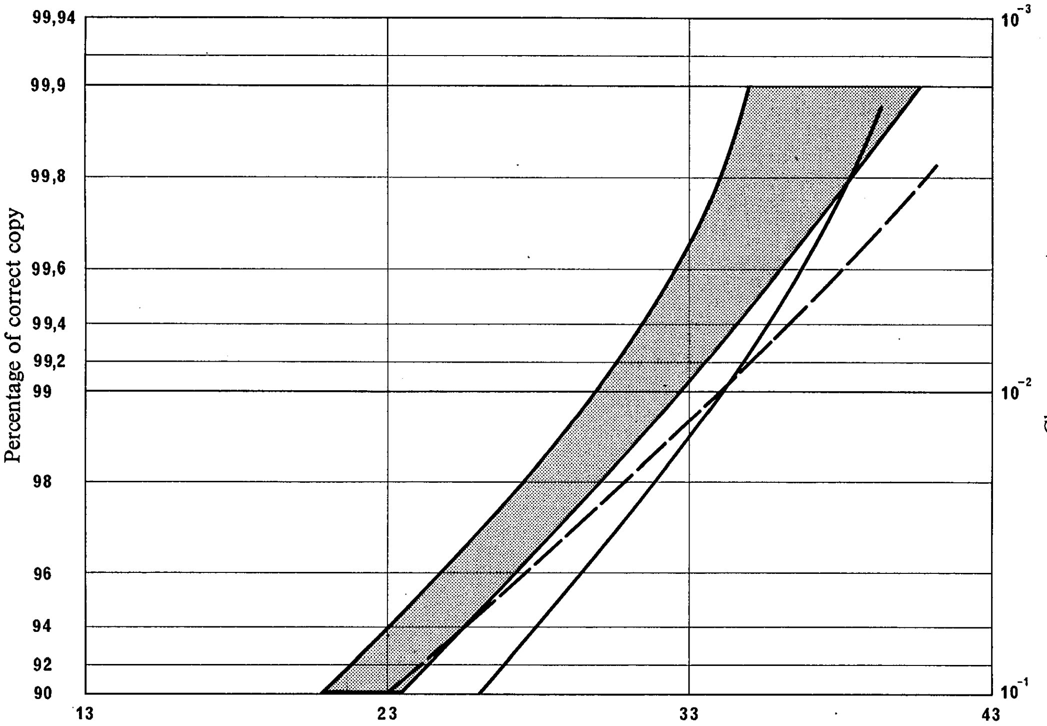
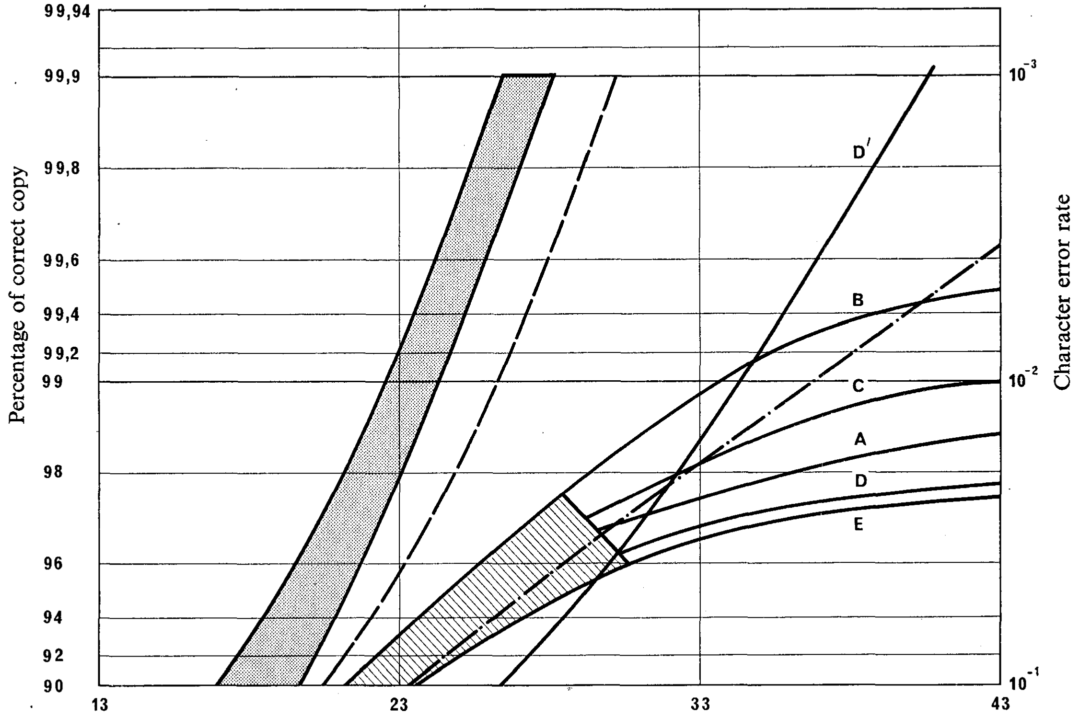


FIGURE 1

Comparison between forward error-correcting systems

Fading rate: 10/min, flat
Detector : filter assessor or limiter-discriminator
Diversity : none

- — — — reference system
- ——— system *D′*
- ▨ other systems



Normalized signal-to-noise ratio at 50 bauds (dB)

FIGURE 2

Comparison between forward error-correcting systems

Fading rate: 10/min, selective, 2 ms path-time difference
Detector : filter assessor or limiter-discriminator
Diversity : none

— — — reference system – filter assessor

▒ all other systems – filter assessor

—·—·— reference system – limiter-discriminator

——— system *D'*

▨ all other systems – limiter-discriminator

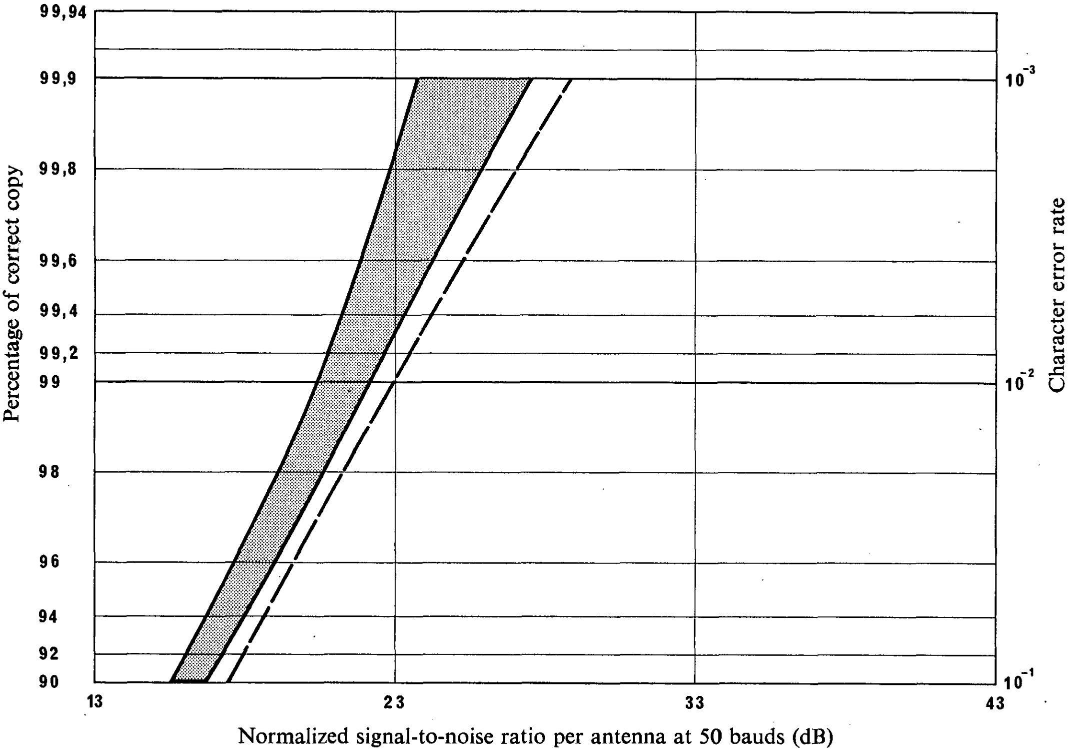


FIGURE 3

Comparison between forward error-correcting systems

Fading rate: 10/min, flat
Detector : filter assessor or limiter-discriminator
Diversity : dual-spaced antennae

— — — reference system

▨ all other systems

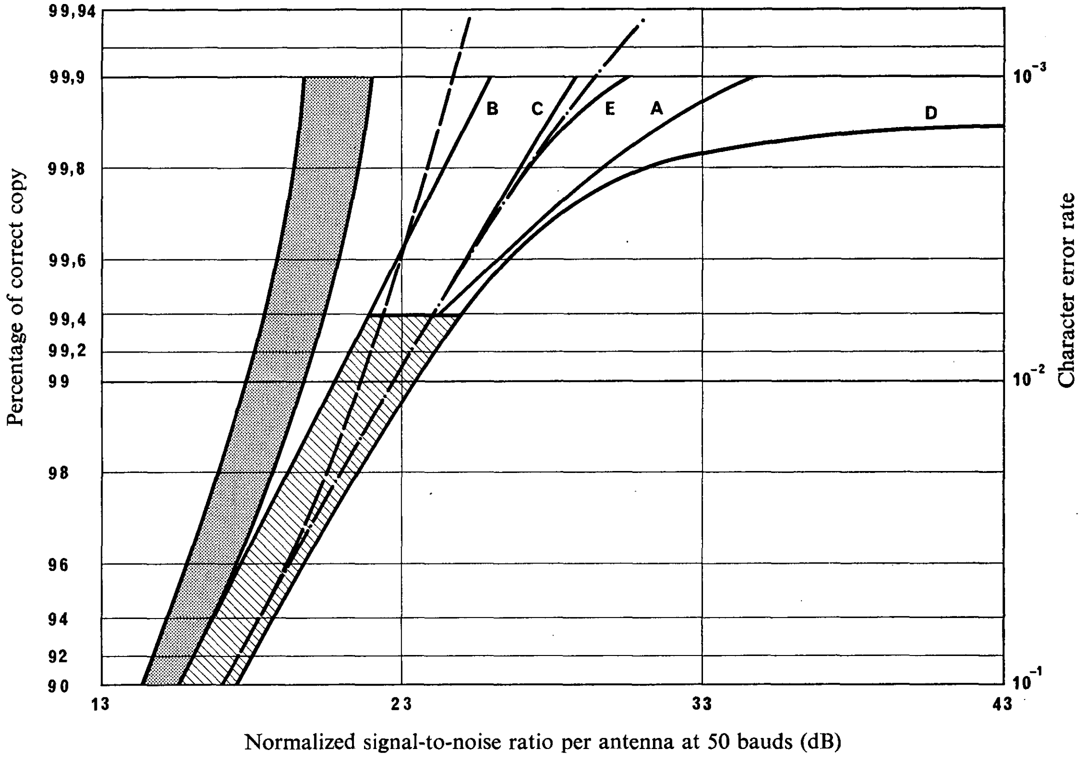


FIGURE 4

Comparison between forward error-correcting systems

Fading rate: 10/min, selective, 2 ms path-time difference
Detector : filter assessor or limiter-discriminator
Diversity : dual-spaced antennae

— — — reference system – filter assessor

▒ all other systems – filter assessor

—·—·— reference system – limiter-discriminator

▨ all other systems – limiter-discriminator

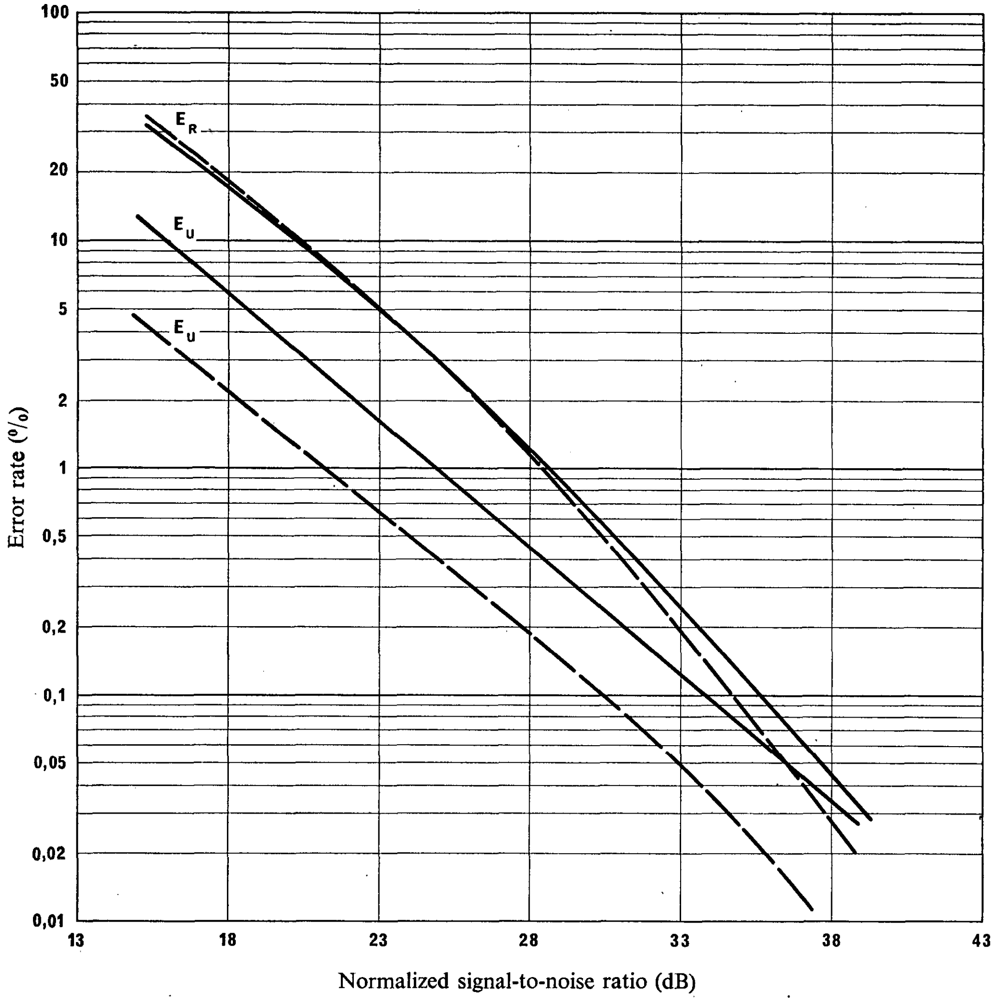


FIGURE 5

Residual error rate (E_R) and undetected error rate (E_u)

Flat fading, 10 fades/minute

———— Normal detection

— — — Detection with zero-position

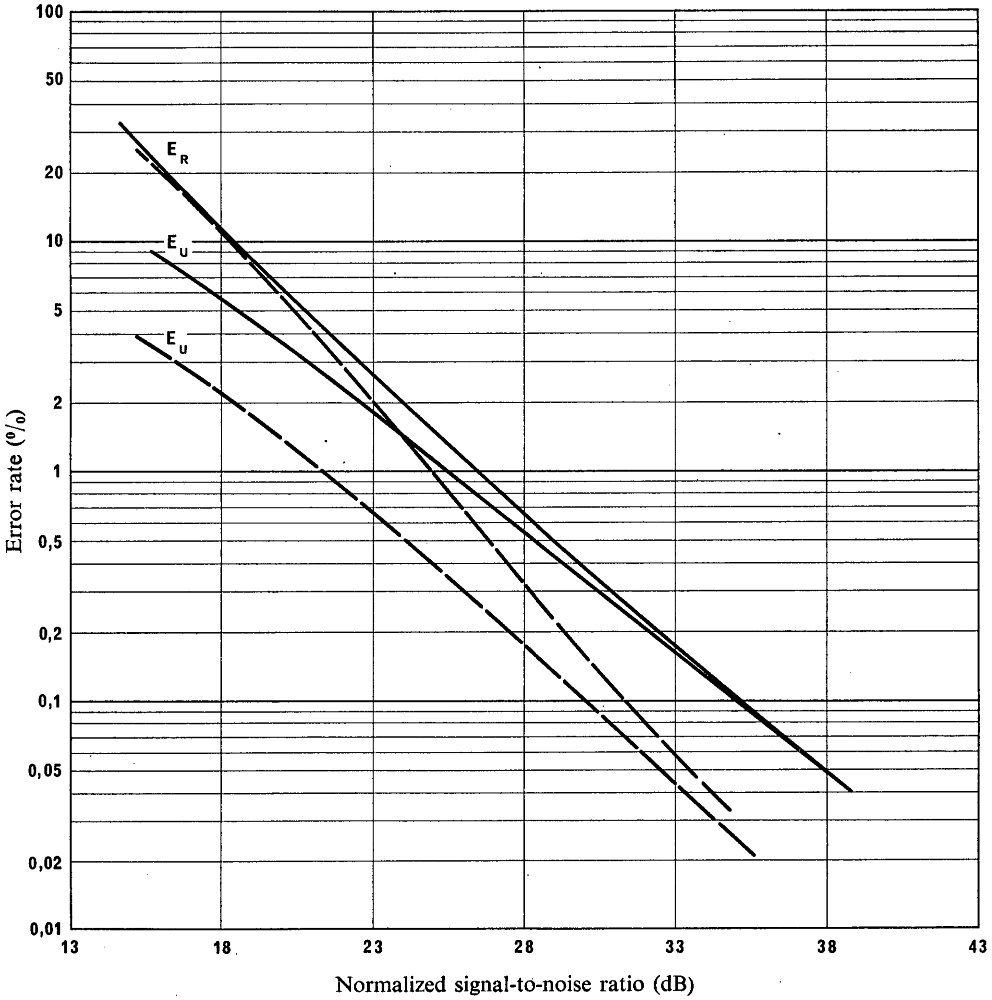


FIGURE 6

Residual error rate (E_R) and undetected error rate (E_u)

Flat fading, 40 fades/minute

——————— Normal detection

— — — — Detection with zero-position

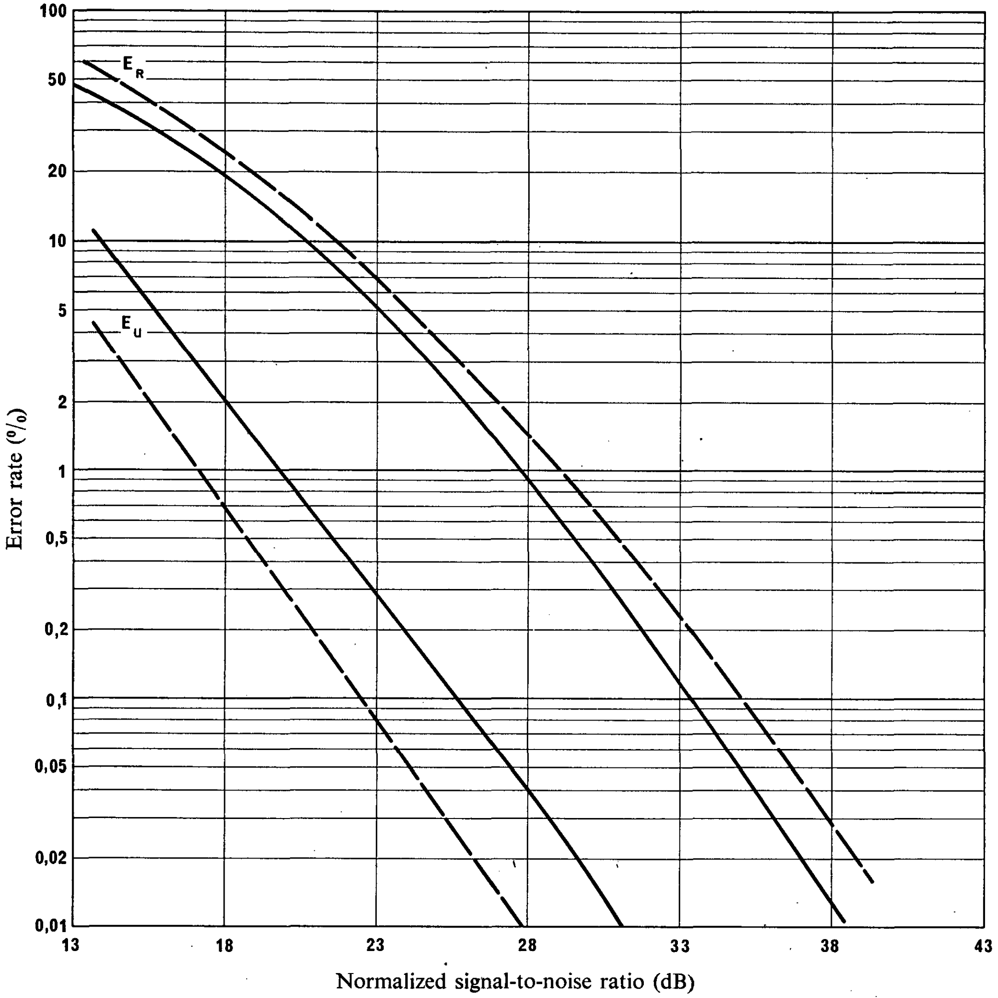
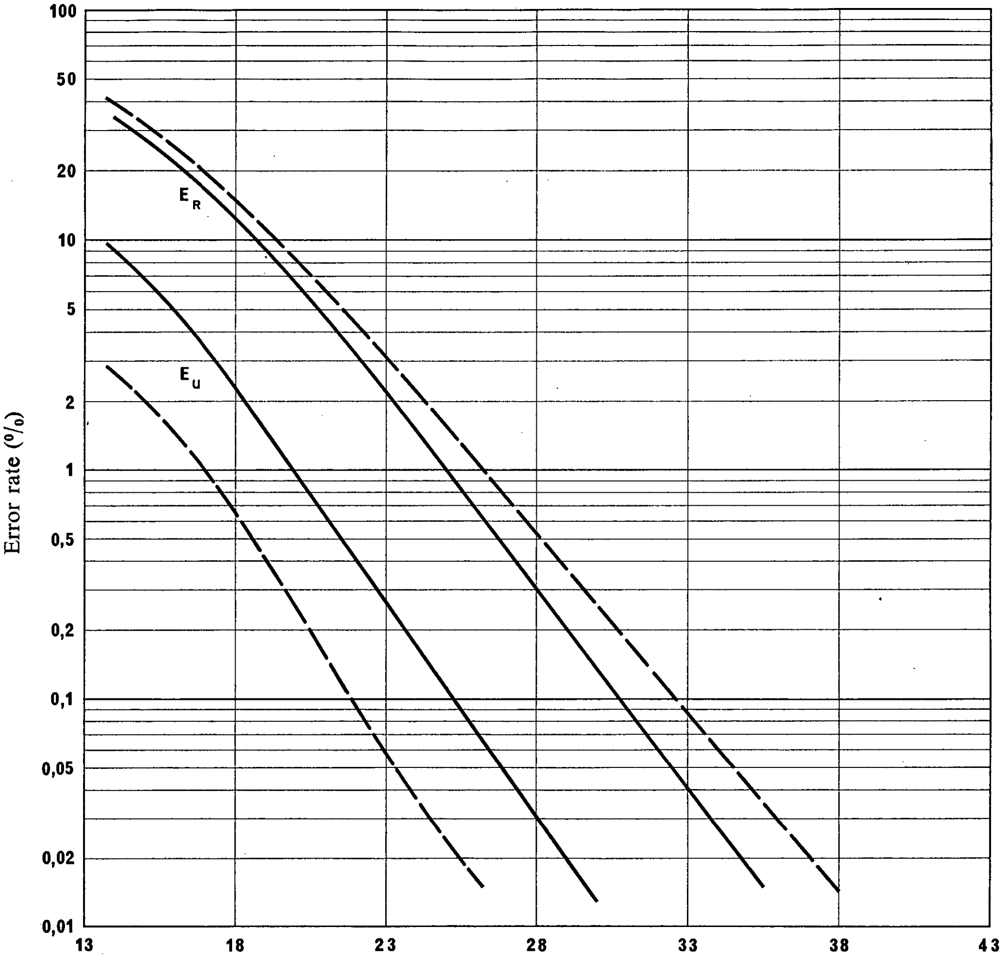


FIGURE 7

Residual error rate (E_R) and undetected error rate (E_u)

Selective fading, 10 fades/minute

—————— Normal detection
— — — — Detection with zero-position



Normalized signal-to-noise ratio (dB)

FIGURE 8

Residual error rate (E_R) and undetected error rate (E_u)

Selective fading, 40 fades/minute

———— Normal detection

— — — Detection with zero-position

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 342-2.

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 342-2, Annex I, §§ 1, 2, 4, 7**, 8*** and 9 where they apply to single-channel operation.

REPORT 351-1*

QUALITY OF PERFORMANCE OF RADIOTELEGRAPH SYSTEMS

(Study Programme 1A-1/3)

(1966 – 1970)

1. Docs. III/23 (Federal Republic of Germany) and III/106 (Rev. 1), pp. 3 to 16 (Companhia Portuguesa Radio Marconi), 1963 – 1966, report on tests which were carried out 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 minutes (Doc. III/23) and intervals of 10 minutes, 1 minute and 20 seconds (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 the telegraph distortion at the radio receiver output. On several circuits, where the efficiency factor was measured over periods of 15 minutes, 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.

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* This Report was adopted unanimously.

** For the purpose of this Report, Recommendation 342-2, § 7.1.2, 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.

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.

2. Doc. III/26 (Federal Republic of Germany), 1966 – 1969, describes an operational piece of equipment which was developed to enable simultaneous monitoring of up to 40 telegraph channels at a single supervisory position. This equipment continuously measures the distortion on each telegraph channel by comparison of two waveforms, one derived directly from the received keyed signal and the other from a local clock which is kept in long term synchronism with the received signal. Since only the absolute value of the distortion is of interest, no difference is made between early and late occurrence of transition points.

The measured distortion is indicated on strips consisting of ten lamps, each lamp representing a distortion range of 5%. The length of a particular illuminated strip thus indicates the degree of distortion occurring on a specific channel. The indicated values are erased every 10 seconds, at which time a new measuring interval starts. Any lamp which is activated within a given measuring interval stays "on" during the remainder of this interval, thus providing a steady and easily readable presentation. At the end of each indicating strip, a specially marked warning lamp is provided which is activated whenever a predetermined degree of distortion is reached. In addition, a 40-track pen recording facility is included which provides for each channel a permanent record of the times that the distortion exceeded the maximum permissible threshold.

Operational use of this equipment has shown it to be of great value in identifying distortion due to unfavourable propagation conditions or misalignment of equipment, as well as providing a means of early detection of deterioration of propagation conditions. As a result, it was found that the efficiency factor of several circuits could be increased by a significant amount by timely initiating corrective measures.

3. Doc. III/82 (United Kingdom), 1966 – 1969, describes the arrangements for centrally controlling a large group of radio receivers. Associated with a control panel for each receiver is a chart recorder with a memory of three hours which shows the level of the pilot carrier and the incidence of telegraph distortion at the receiver output. The latter information is derived from a telegraph distortion (short element) counter, set up to operate at 30% element distortion which continually feeds an element integrater having a time constant of 80 seconds. The recorder is set so that the full scale deflection corresponds to 10% of the elements exceeding 30% distortion.

This is found to be a sensitive method of assessing the quality of the received signal and preferable to the use of efficiency factor which is often determined by circumstances other than the propagation conditions over the radio path.

4. Doc. III/95 (U.S.S.R.), 1966 – 1969, reports on measurements of the transmission quality of a number of radiotelegraph circuits in the U.S.S.R., made throughout the years 1966 – 1968.

To evaluate transmission quality the degree of distortion was determined as that part of the total number of element transitions occurring in intervals of 60 seconds, that deviated by more than a predetermined limit of 40% from the element transitions generated by an element synchronizer.

The transmission quality η, called the factor of satisfactory operation, was derived from this as the relative number of acceptable elements registered by a recorder. The store feeding the recorder is reset every minute to its zero position [3, 4].

Experimental tests on circuits of 2800, 5100 and 5400 km length showed an annual behaviour of the factor of satisfactory operation with values between 0·87 and 0·92 in winter, and between 0·92 and 0·95 in summer [5]. The correlation γ between the degree of element distortion and the character error rate is closer when the element distortion becomes more pronounced. For distortion exceeding 40%, γ was found to be greater than 0·85.

5. Conclusions

The experience gained since 1963 seems to indicate that the measurement of telegraph distortion is a more direct and appropriate way to assess transmission quality of radiotelegraph channels than the measurement of the efficiency factor. However, in those cases where it is impossible to use the value of measured telegraph distortion for the improvement of the efficiency of ARQ-circuits, as for instance with a "flex" system*, the measurement of channel efficiency might be operationally preferable.

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REPORT 352**

USE OF PRE-EMPHASIS AND DE-EMPHASIS FOR PHOTOTELEGRAPH TRANSMISSION OVER HF RADIO CIRCUITS

(Study Programme 1A-1/3)

(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.

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* See Report 436.

** This Report was adopted unanimously.

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 435*

ERROR STATISTICS AND ERROR CONTROL IN DIGITAL TRANSMISSION OVER OPERATING RADIO CIRCUITS

(Study Programme 18A/1)**

(1970)

1. Introduction

This Report describes some studies on error statistics in digital transmission over operating HF radio circuits. Some studies on the applicability of error control techniques are also included.

2. Error statistics

Brayer [1] reports error-pattern data gathered from operational HF digital data transmission systems over long haul trans-equatorial paths. In one test, a four-level time differential phase-shift keying (PSK) modem with eight and sixteen tones for transmission rates of 1200 and 2400 bits/s, respectively, was used. In another test, three different types of PSK modems were used. In both tests, a sixteen-tone frequency-shift-keyed modem was used for reference purposes.

Error patterns are classified into three classes:

— relatively random patterns,

— burst-error patterns,

— systematic error patterns (periodicity).

Cumulative distributions of error-free gap length show the frequent occurrence of periodic error patterns with the period corresponding to the number of sub-channels in the modem. It appears also, that the probability of short gaps is generally much higher than what would be expected from independent error patterns.

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* This Report was adopted unanimously.

** This Study Programme replaces Study Programme 5A/III.

Moyes and Taylor [2] report error statistics collected on a 5000 km medium-latitude HF path. A binary frequency-shift keying modem (without frequency-division multiplexing) was used at a transmission rate of approximately 72 bits/s. The average bit error rate for the entire test was $4{\cdot}7 \times 10^{-4}$ which is normal over this path. The data showed pronounced clustering of errors.

Greim [3] reports error statistics collected on an HF teleprinter link from Bermuda to New York. A frequency-shift keying 60 words/min circuit modem was used with a frequency shift of ± 170 Hz. The data indicated that errors were dependent and highly correlated.

Konopleva (see Report 197-2, § 4 and [4, 5]) gives experimental results on the dependency of error rate on distance.

3. Error-control techniques

Brayer and Cardinale [4, 5] report computer-simulated studies on the effectiveness of error-control techniques applied to the data they reported. The results indicate that:

- relatively random error patterns which, in general, were found to occur only at error rates of 1×10^{-4} and lower, can be corrected by applying long block codes such as the Bose-Chaudhuri (255, 123, 19) code;
- for burst type error patterns this type of code is not effective. For these patterns a relatively short block code, such as a modified Golay (24, 12, 3) code, with interleaving can be applied effectively;
- a relatively short block code with interleaving is also effective for relatively random patterns. All patterns which could be corrected by a (255, 123, 19) code could also be corrected by interleaving nine blocks of the (24, 12, 3) code;
- for periodic patterns the choice of the number of blocks to be interleaved is extremely important;
- a Massey half-rate diffuse convolutional code performed at least as well as any of the above interleaved or non-interleaved block code techniques.

Moyes and Taylor [2] give the distribution of blocks of length n (n = 15, 21, 23, 31, 33, 35, 39, 45, 51, 63) which have m or less errors after applying interleaving of up to 32 s, as well as the same distribution without interleaving. These statistics indicate that the block code with and without interleaving improved the character error rate by approximately three and two orders of magnitude, respectively, over the raw character error rate.

Kohlenberg [6] provides an example of the relationship between error statistics and code used. On a tropospheric circuit with burst type error statistics, a particular diffuse convolutional code gave about one order of magnitude improvement for an uncorrected channel error rate of 0·1, about two orders of magnitude for an uncorrected error rate of 0·01, while for an uncorrected error rate of 1×10^{-3} the decoded error rate was too low to be measured within the framework of the test. He points out that the use of this same code on the same channel but with a randomized error rate of 0·1 would have degraded the channel rather than improved it.

Greim [3] analyzed the teleprinter error data and concluded that:

— multiple bit-errors per character error are common, which may preclude effective operation of parity type error detection or error correction schemes;

— although more than one character error is likely to be experienced within a one-minute interval, extreme bunching (greater than eight) of character errors is unlikely.

Fontaine [7] studied error control techniques applied to HF radio teleprinter channels based on Greim's data [3]. The results indicate that:

— error-correcting codes are impractical for improving the reliability of a teleprinter channel; however, he did not consider interleaving of code words;

— error detecting and repeat schemes with about 10% redundancy will reduce the probability of error to a negligible amount.

Moyes [8] reports on-the-air comparison tests at teleprinter speeds over a path from Hawaii to New Jersey. Two codes were evaluated, a non-interleaved Bose-Chaudhuri (15, 7) code, and a Wagner code. In this latter code, a single parity bit is included with each teleprinter character; in case of a parity error at the receiver, a bit-energy detector determines the least reliable bit in the character and reverses its polarity. It was found that both codes gave at least an order of magnitude improvement for an uncorrected character error rate of approximately 5×10^{-4}.

Goldberg *et al.* [9] investigated the effectiveness of various codes on data collected on a 4000 km HF path from California to New Jersey, using a modulation rate of 75 bits per second. Results given for a specific run of approximately 60 000 bits having an uncorrected error rate of 1×10^{-3} show that:

— a Gallager type half-rate convolutional code reduced the number of errors from 61 to 4;

— a Massey type half-rate convolutional code resulted in no output errors;

— an interleaved (23, 12, 3) Golay code would have corrected all errors, with as few as 10 (the smallest number tried) blocks interleaved.

An analysis of the collected data also showed the burst nature of error patterns and the occurrence of periodic error patterns corresponding to the number of sub-channels.

4. Conclusions

All the studies reviewed here agree at the point that the observed error patterns are, in general, very different from random patterns, which would be expected with independent occurrence of binary errors. Instead, errors tend to cluster, and when the modulation technique includes frequency-division multiplexing, periodicity of error pattern may sometimes be observed.

The effectiveness of short block codes with interleaving [2, 4, 9], diffuse convolutional codes [5, 9], and error detection and repeat schemes [7] appears to be well established. However, procedures to select the best technique for a particular channel and particular desired error rate have not yet been established. Comparison between the various studies is difficult as the parameters of the tests reported vary widely.

There seems to be no single statistic of error data which can be used to compare different error control schemes. For example, the statistics asked in C.C.I.R. Study Programme 18A/1, § 3, are useful only to study the effectiveness of block codes without interleaving, and are of little or no help in the study of other techniques. If statistics are derived for one particular aspect of the data, some other aspects of this data will be lost. It is, therefore, recommended that the publication of raw error data be encouraged so that everyone can use the data to compare different techniques, including possible ones to be devised in the future. A rough estimate indicates that all the raw data analyzed by Brayer and Cardinale [4] can be printed as a computer print-out of approximately 100 pages, which is not a prohibitive amount.

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REPORT 436*

EFFICIENT USE OF HF RADIOTELEGRAPH CHANNELS IN THE TELEX NETWORK BY MEANS OF AUTOMATIC SELECTION AND ALLOCATION PROCEDURES

(Study Programme 1A-1/3)

(1970)

1. Introduction

HF radio circuits are frequently used to link telex networks. The transmission of information passed over such circuits is protected to a sufficient degree by means of duplex ARQ circuits, the main characteristics of which are laid down in Recommendation 342-2.

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* This Report was adopted unanimously.

The traffic delays occurring in ARQ circuits during periods of conditions unfavourable to radio reception are, due to cycling, of variable duration and interfere with fully automatic switching of telex circuits.

2. In view of the decision by the C.C.I.T.T. that charging on a fully automatic telex network should be made on the basis of elapsed time rather than on non-cycling time, it is desirable that radio sections of a fully automatic switched network should be designed to provide a good quality of service, while protecting the users against unreasonable charges. The main characteristics of such a system, called the "flex" system, are described in the Annex.

3. The development of the "flex" system is based on the following principles and consideration:

3.1 The efficiency of each ARQ channel is monitored continuously. A given telex circuit will be cleared when the efficiency drops below a predetermined value and a new circuit is established, utilizing another ARQ channel of acceptable efficiency, to enable the subscriber to complete his call.

3.2 Although large parts of a telex circuit are duplex, it is to be noted that telex operation is basically simplex. The ARQ part of the circuit has the disposal of a "go" path and a "return" path, for which a radiotelegraph channel is busied in each direction. Depending on the direction into which information is transmitted in simplex operation, each of the radiotelegraph channels will function alternately as a go or as a return path. The return path is needed to close the ARQ loop, but no information is passed over it. Thus, in effect, only 50% of the total channel capacity is utilized. Moreover, during a telex connection, idle-time signals are transmitted over the go path when the active subscriber is not actually transmitting (stop intervals), with the result that, on the average, the channel utilization is even less than 50% of the total capacity.

3.3 If, for the destination considered, several ARQ circuits are available, a subscriber can be offered a circuit that is substantially free from cycling, if a method of re-routing his traffic is found, each time the busied ARQ circuit becomes inefficient. This method does not only offer improved service to the subscriber, but also increases utilization of the radiotelegraph channels. Thus, an ARQ loop will no longer serve as the go path in one direction and the return path in the other direction for one pair of subscribers, but each direction of the ARQ loop becomes a go path for a separate pair of subscribers, of whom the active subscriber occupies that go path as long as his traffic can be transmitted over it. In addition, during periods in which a large amount of traffic is offered, traffic that would otherwise be held up can, with this system, be transmitted over the available channels during idle periods of calls in progress.

ANNEX

1. The "flex" system is a method that deals with the automatic connection and disconnection of telex circuits to and from ARQ channels, which makes it possible:

1.1 to re-route telex circuits from ARQ channels in which the efficiency has dropped below a predetermined value to ARQ channels that are efficient;

1.2 to disconnect an ARQ channel from a telex circuit during the idle intervals in the traffic flow, so that the ARQ channel becomes available for another telex circuit;

1.3 to allot each of both paths of an ARQ channel to different telex circuits;

1.4 to effect forced clearing of a telex circuit if none of the functions described in §§ 1.1, 1.2 or 1.3 can be performed.

2. An ARQ channel is connected to the telex network at both ends via a telex adaptor panel (hereafter referred to as TP), which performs the functions prescribed in C.C.I.T.T. Recommendation U.20.

A number, *N*, of TP terminals and a number, *M*, of ARQ channels are interconnected by the automatic switching device of the flex system (*N* and *M* need not necessarily be equal). This arrangement replaces the direct connection between a TP and a specific ARQ channel via a patching board in conventional ARQ circuits.

3. If no telex circuit is established, all the TP in the flex system are disconnected from the ARQ channels, and all non-cycling ARQ channels transmit "signal β".

4. At the interface to the flex system, each TP has a sending and a receiving terminal. The sending terminal of a TP is automatically connected to the front end of an efficient ARQ channel when, from the landline circuit:

— a call criterion is received by the TP,

— traffic is brought into the storage device of the TP,

— a clearing criterion is received by the TP.

5. The front end of an ARQ channel can only be seized, if:

— the ARQ channel is efficient,

— the ARQ channel is not cycling,

— the front end has not yet been allotted to another TP.

6. Associated with each TP is an address generator which, as soon as the TP sending terminal is connected to the front end of an ARQ channel, transmits the address signal over this connection. The address signal is specific for each individual TP, and consists of a 5-unit signal, transmitted thrice in succession. The remote ARQ receiver recognizes a signal as an address, when at least two out of three signals are identical, and this group has been preceded by at least two consecutive "signals β". (It is considered that for an efficient ARQ channel the probability of receiving two transposed signals in a group of three, without a fault being detected, is extremely low.)

7. At its receiving end, the ARQ channel finds the corresponding TP receiving end terminal by means of the address signal.

8. A circuit is established to pass:

— a call,

— traffic,

— a clearing signal.

8.1 To pass a call over the ARQ channel, only the address is transmitted. The reception of only the address at an ARQ receiving terminal puts the required TP receiving end to the "called" position.

8.2 Traffic signals transferred over an ARQ channel immediately follow the address signal. The TP receiving terminal is disconnected from an ARQ go path as soon as the traffic flow is interrupted by pause signals (on the ARQ path at least two consecutive "signals β").

8.3 To pass a clearing signal over an ARQ channel, the address signal is immediately followed by seven "signals α". On receipt of two consecutive "signals α" the TP receiving end accepts the clearing condition after which it is disconnected from the ARQ receiver by the flex system.

9. The flex system disconnects a TP sending end from an ARQ front end when:

— during traffic, the traffic flow is interrupted because the TP storage is empty, and moreover three consecutive "signals β" have been successfully transmitted over the ARQ path,

— no traffic is yet available after a call signal has been passed, and three consecutive "signals β" have been transferred over the ARQ path,

— at reception of a clearing signal, seven consecutive "signals α" and three consecutive "signals β" have been passed over the ARQ channel,

— the efficiency of the ARQ channel drops below the predetermined value.

In the last case, the disconnecting of the TP sending end from an ARQ channel might cause the loss of three characters stored in the ARQ storage. However, the disconnecting and re-routing of a TP-user can be performed without loss of characters, by utilization of the system cycle in conjunction with an externally added dummy cycling storage.

10. A peculiar situation arises when a TP-user has a telex circuit at his disposal but fails to re-establish an ARQ connection because all efficient ARQ channels are engaged. In such a case one of these channels is temporarily disconnected from the transmitting TP busying it, and is allotted to the first mentioned TP, only to enable it to transmit a forced clearing signal over the ARQ route. The ARQ channel is returned to its previous user as soon as this clearing signal has been transmitted.

The clearing signal is also sent to the subscriber who was using the TP that cleared the connection over the ARQ route.

REPORT 437*

OPERATIONAL USE OF THE EFFICIENCY FACTOR

(Study Programme 1C/3)

(1970)

1. Introduction

With the introduction of fully automatic switching for international telex services in world-wide networks, the establishment of appropriate criteria for determining when an HF radio channel can be switched in or should be switched out of the circuit has become urgent.

Doc. III/20 (Japan), 1966 – 1969, reports on a series of tests carried out during the month typical of a season, i.e. January, June and October, over HF radio channels between Tokyo and San Francisco, Manila, Brussels, Buenos Aires and Hong Kong.

Doc. III/87 (Rev. 1) and Corrigendum to Doc. III/87 (People's Republic of Poland), 1966 – 1969, describes work carried out on circuits between Warsaw and New York in which the autocorrelation of the efficiency factor was determined for differing circuit conditions.

2. Results

2.1 A criterion that the efficiency factor is above 80% for an integration period of 20 s immediately prior to the establishment of a circuit is deemed acceptable for switching an operational radiotelegraph channel into the network. It was found that when this criterion is met the probability that the efficiency factor will remain above 80% for the next 8 minutes (average duration of a call) is 97%.

2.2 A criterion that, when the efficiency factor falls below 80% for an integration period of 60 s, an existing call should be interrupted was deemed to be inappropriate. Instead, it was found acceptable to use as a criterion that when the average value of the efficiency factor, integrated

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* This Report was adopted unanimously.

over the cumulative time period of the call, falls below 80% the call should be interrupted. Using this latter criterion, the average overcharge for a hypothetical call of 8 minutes duration for the routes Tokyo-Brussels and Tokyo-Manila was found to be 7%.

2.3 However, the auto-correlation studies show that with an observation time of 20 consecutive 20-s periods (400 s in all) the circuit conditions may only be reliably predictable for periods of as high as 200 s depending upon the stability of the circuit conditions.

2.4 It was found that the statistical properties of the time behaviour of the efficiency factor vary as a function of year, season, distance and direction of the radio circuit. For this reason, it is recommended that for any specific circuit, observations of the efficiency factor should be carried out over a period sufficiently long to permit a decision to be made as to whether or not the circuit can be used in the fully automatic switched telex network.

QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS

(STUDY GROUP 3)

QUESTION 1/3

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?

STUDY PROGRAMME 1A-1/3

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 – 1970)

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 studies 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 service:

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 Telegraph Alphabet No. 2;
- other systems.

1.3 *Facsimile, phototelegraphy*

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 the quality of radiotelegraph circuits (telegraph distortion; character error rate; efficiency factor for ARQ circuits);

2.1.3 legibility of copy over facsimile (phototelegraphy) 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;

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* 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.

Note. — 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.

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:

- 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 monthy 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, Report 252-2 gives a method for computation.

This study is intended to lead to revisions or replacement of Recommendations 240-1, 339-2 and 340.

2.3 Minimum bandwidth required for satisfactory transmission and reception of the intelligence in a complete system.

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 240-1.

ANNEX

MINIMUM PROTECTION RATIOS AND FREQUENCY SEPARATIONS 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)																								
	50 bauds (printer)																								
	120 bauds (recorder)																								
F1	50 bauds (printer)																								
	120 bauds (recorder)																								
	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.

STUDY PROGRAMME 1B/3

USE OF PILOT CARRIER IN SINGLE- AND INDEPENDENT-SIDEBAND SYSTEMS

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

CONSIDERING

(a) that single-sideband and independent-sideband radio systems in the fixed service commonly use a reduced level pilot carrier for controlling the gain and frequency tracking of the receiver;

(b) that a pilot carrier level of –26 dB relative to peak envelope power has been widely used on independent-sideband radio telephone systems;

(c) that the level of pilot carrier used by other types of system, such as radiotelephony using a frequency-modulated control channel and frequency-division multiplex telegraph systems, is governed by different considerations from those applying to conventional radiotelephony;

(d) that advances in technique in the design of transmitters and receivers, including the application of automatic methods of operation, render a reappraisal of current practice desirable;

(e) that in the interest of operational simplicity a standard level of pilot carrier common to all types of system may prove desirable;

(f) that improvements in the frequency stability of carrier generating sources make it possible to consider dispensing with the frequency control functions of the pilot carrier in certain cases;

(g) that the general aim is to ensure that circuit failure due to contamination of the pilot carrier channel by noise at the receiver does not occur whilst the signal in the communication channel is otherwise commercial;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the levels of the pilot carrier for the various systems which will lead to the most efficient communication, bearing in mind the current state of development in transmitting and receiving equipment;
2. consideration of the advantages which would result from the use of a standard level for all systems using a pilot carrier;
3. determination in what cases and under what circumstances a pilot carrier could be dispensed with.

STUDY PROGRAMME 1C/3*

EFFICIENCY FACTOR AND TELEGRAPH DISTORTION ON ARQ CIRCUITS

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

CONSIDERING

(a) that the efficiency factor as defined in the "List of Definitions of Essential Telecommunication Terms" (Part I, 1961, No. 33.23; see also Recommendation 345), is very useful for defining and determining the quality of a communication circuit using error correction by automatic repetition;

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* This Study Programme replaces Study Programme 18A/III.

(b) that the value of the efficiency factor of an ARQ circuit depends on the telegraph distortion in both directions of the radio circuit;

(c) that a continuous measurement of the efficiency factor is required by the C.C.I.T.T. for radio telegraph circuits incorporating ARQ equipment, and operating in the fully automatic telex network (see Recommendation U.23, C.C.I.T.T., Mar del Plata, 1968);

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the way in which measurements of the efficiency factor may be used to analyze and predict the performance of systems with error correction by automatic repetition, especially at the commencement and finish of the operating period using one frequency;

2. the way in which the efficiency factor depends on the telegraph distortion measured at the incoming end (receiver) of the ARQ terminals at either end;

Note 1. — Measurements should preferably be carried out in successive periods of 20 seconds for detailed analysis and over a number of such periods for long period evaluation.

Note 2. — Attention is especially drawn to § 9 of Recommendation U.23 of the C.C.I.T.T. with regard to the monitoring of ARQ circuits, which reads:

"9. *Precautions to be taken before incorporating circuits with ARQ equipment in automatic switching networks*

In spite of these precautions, fully automatic operation on a radiotelegraph circuit incorporating ARQ equipment can be considered only if this circuit possesses adequate stability.

Before incorporating a circuit with ARQ equipment in the fully automatic switching network, the Administrations (or the Recognized Private Operating Agencies) must carry out extended trials.

These trials should be made under normal traffic conditions, over a minimum period of three consecutive hours chosen from the busy period (or periods), when heavy traffic is foreseen to occur on the route under consideration (allowing for the traffic, whether terminal or transit which prevails on the route according to the season).

The condition which must be fulfilled before a circuit can be accepted for use in the fully automatic network is that its mean efficiency factor, measured over periods of 20 consecutive seconds each, shall not fall below 80% for more than 10% of the total time involved in the measurements.

The measurements must be repeated as often as will be necessary for the Administration to have an assessment of the suitability of the circuit.

The attention of Administrations is drawn to the fact that, before offering fully automatic transit working on a radio route incorporating ARQ equipment, the grade of service on the route under consideration must be in accordance with that proposed in Recommendation F.68, § 11*b)*, i.e. only one call lost in 50.

If these conditions are not complied with, it would be better to retain semi-automatic operation."

QUESTION 2/3

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;

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 3/3

DIRECTIVITY OF ANTENNAE AT GREAT DISTANCES

The C.C.I.R. , (1948 - 1951 - 1953)

DECIDES that the following question should be studied:

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.

STUDY PROGRAMME 3A-1/3

IMPROVEMENT OBTAINABLE FROM THE USE OF DIRECTIONAL ANTENNAE

The C.C.I.R., (1953 - 1956 - 1959 - 1970)

CONSIDERING

(a) that Study Programme 1A-1/3 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 performance of a system under fading conditions may also be improved by the use of appropriate directional antennae;

(c) that it is important to know the discrimination given by directional antennae for various ranges and directions of both the wanted and the interfering stations;

(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, and should specify the directions of the wanted and interfering signals;

3. the effect of the antenna directivity pattern (antenna diagram) in reducing multipath distortion;

4. the effects of the antenna height in increasing the number of hours of useful transmission and in the reduction of interference;

5. the usefulness of a null method of minimizing the interference. The data required to evaluate the usefulness might consist of:

5.1 logs of commercial receiving stations, showing outages due solely to interference and the relative azimuth bearing of interfering stations,

5.2 experimental data on the use of directional antenna systems and antennae with adjustable directions of null, under conditions where interference is experienced.

STUDY PROGRAMME 3B/3

DIRECTIVITY OF ANTENNAE FOR THE FIXED SERVICE 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 service;

(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;

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* The median values of the gain can also be expressed relative to the isotropic antenna.

UNANIMOUSLY DECIDES that the following studies should be carried out:

studies of the desirable characteristics of the directivity of transmitting and receiving antennae for the international fixed service, 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.

QUESTION 4/3

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 7/3

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 246-2 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 436-1;

(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 hertz while instantaneous deviations may reach much higher values (see Report 111 and the Annex to Recommendation 349-2);

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 349-2);

— the frequency deviations referred to in § 1?

QUESTION 8/3

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 shift is preferable);

c.b the possible advantage of frequency diversity for reception (an advantage which increases with shift);

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 shift 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 shift 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.

QUESTION 12/3

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 a 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 13/3

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 14/3

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 16/3

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) and for the C.C.I.T.T. intercontinental signalling systems Nos. 5 and 5 bis appear in the White Book, Vol. VI, Parts IX, X and XI respectively.

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 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-1/3*

VOICE-FREQUENCY (CARRIER) TELEGRAPHY ON RADIO CIRCUITS

The C.C.I.R., (1951 - 1953 - 1959 - 1966 - 1970)

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:

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* This Study Programme does not derive from any Question under study.

- — 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 (hertz)/modulation rate (bauds)), the channel spacing and the parameters of the regenerators on the error rate.

STUDY PROGRAMME 20A/3*

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;

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* This Study Programme does not derive from any Question under study.

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/6) 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 cooperation between the greatest number of users.

QUESTION 21/3

HF IONOSPHERIC CHANNEL SIMULATORS*

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

CONSIDERING

(a) that on circuits operating in band 7 (HF), the distortion caused by multipath effects, manifested by selective fading and time-variant frequency-spread and delay-distortion, degrades the quality of the received signals;

(b) that the type of multipath effect encountered differs appreciably depending on the length of the radio circuit, its global routing and the frequency used for transmission, and thus gives rise to a wide range of distortion and fading patterns;

(c) that for a particular system of transmission, the performance of a radio circuit may differ appreciably with differing types of distortion and fading;

(d) that fading simulators or ionospheric channel simulators have been constructed by various laboratories and are useful instruments to study system performance;

(e) that it is essential for the time variant distortion and fading patterns generated in the simulator to be representative for the patterns actually encountered on such radio paths;

(f) that it is desirable for such a simulator to take account of atmospheric and man-made noise characteristics, and to facilitate study of interference between signals;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what patterns of fading, time-variant frequency spread and delay distortion should be considered as giving markedly differing types of circuit performance;

2. how should these patterns, and the parameters of a model of HF ionospheric transmission, be specified so as to assure fully representative laboratory simulation of various transmission conditions in band 7;

3. how should atmospheric and man-made noise be represented, and how can a simulator be used to study interference between signals?

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* This Question has been brought to the attention of Study Group 6.

QUESTION 22/3*

TRANSPORTABLE FIXED SERVICE RADIOCOMMUNICATION EQUIPMENT FOR RELIEF OPERATIONS

(1972)

The C.C.I.R.,

CONSIDERING

(a) that rapid and reliable telecommunications are essential for relief operations in the event of natural disasters, epidemics, famines and similar emergencies;

(b) that, through damage or from other causes, the normal telecommunications facilities in disaster areas are often inadequate for relief operations and cannot be restored or supplemented quickly through local resources;

(c) that the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971) has adopted Recommendation No. Spa2 - 13;

DECIDES that the following question should be studied:

what are the preferred characteristics and frequency bands for transportable fixed service equipment, operating at frequencies below approximately 30 MHz, for the provision of relief telecommunications when:

— the equipment is used in liaison with a transportable earth station;

— only terrestrial relief telecommunication facilities are involved?

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* See also Questions 22/4, 22/8 and 20/9.

STANDARD FREQUENCIES AND TIME SIGNALS

STUDY GROUP 7

Terms of reference:

— to coordinate a world-wide time service of standard frequency and time signal emissions;

— to study the technical aspects of emission and reception in this service and to improve the accuracy of measurement.

Chairman: J. T. Henderson (Canada)
Vice-Chairman: G. Becker (Federal Republic of Germany)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 7

Implementation of the terms of reference will require knowledge and understanding of much that has heretofore been considered necessary only for laboratories and observatories, and will require that the needs of the users of such services be kept in mind.

Changing conditions will modify, and undoubtedly greatly extend, the role of the C.C.I.R. in the area of frequency and time, for the gap between research and application in this area is small. The feedback to research from new methods or new systems has been eagerly absorbed. A rough classification of interests in the time-frequency domain would include:

— research on frequency or time,

— time keeping,

— direct utilization (i.e. disseminating time or frequency signals including problems relating to interference),

— *systems* dependent on time or frequency as a primary parameter.

It is apparent there will be much activity in these subjects in the next decade, at least, and all concerned must keep the broad picture in mind regardless of individual specialization.

Research on atomic standards of frequency have reached the point where they now provide the best clocks available and indeed have reached the point where the frequency standards themselves are best intercompared by comparing, over long intervals, the clocks controlled by these standards. It is predictable therefore and also necessary that Study Group 7 keep in close touch with the appropriate bodies of the scientific unions dealing with matters of frequency and time. In particular, the C.C.I.R. must keep in close touch with the operation of the Bureau international de l'Heure, which has rendered such excellent service in the past. In any event, Administrations furnishing standard frequency or time signal services will have to carefully consider their position with respect to time keeping.

In this context, Study Group 7 should be able to render useful advice to countries considering installing services for the use of standard-frequency and time-signal emissions and would welcome participation by any of them in its meetings.

The precision of synchronization between clocks in different parts of the world has encouraged study of at least one system which is dependent on accurate time and having aeronautical applications. This has modified ideas within Study Group 7 regarding the precision of synchronization usable by industry. There seems little doubt that other time-based systems will appear, for as yet undefined applications, relying on accuracies both unattainable and unusable in the past.

Before such systems using accurate time further complicate the mutual interference problem which already exists between standard signals, action should be taken to reduce the problem and it is hoped widespread research will be done on the subject.

New methods of synchronization and new methods of time dissemination, some already reported upon, will unquestionably be needed and such work should be encouraged. It is doubtful if any single system will satisfy all future requirements. Transportable caesium clocks have been shown to be extremely accurate; although an expensive solution, it does not seem to have reached its ultimate accuracy. Comparisons via satellite, or use of the high accuracy of atomic standards for satellite telecommunications have by no means been fully exploited, and it goes without saying these methods are certain to receive attention. Publications have noted possibilities for synchronizing time to within about 5 μs on a world-wide basis using radar signals from the Moon. The possibilities of the stabilized lasers are just emerging so the next decade should prove a fruitful one for Study Group 7 if adequate effort is applied in the proper quarter.

STUDY GROUP 7: STANDARD FREQUENCIES AND TIME SIGNALS

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 374-2

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

The C.C.I.R., (1951 – 1953 – 1956 – 1959 – 1963 – 1966 – 1970)

CONSIDERING

(a) that the Administrative Radio Conference, Geneva, 1959, allocated the frequency bands 20 kHz ± 0·05 kHz, 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;

(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 7;

(e) that the second was defined by the 13th General Conference of Weights and Measures (1967) as follows: "The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium atom 133";

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 offset 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 adjustments 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 0000 h 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;

8. that this Recommendation shall apply until 0000 h UT, 1 January 1972, and will then be replaced by the provisions of Recommendation 460 together with detailed instructions to be adopted by Study Group 7 after consideration of the Report of Interim Working Party 7/1 in conformity with Resolution 53.

RECOMMENDATION 375-1

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/7)

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 376-1

AVOIDANCE OF EXTERNAL INTERFERENCE WITH EMISSIONS OF THE STANDARD-FREQUENCY SERVICE IN THE BANDS ALLOCATED TO THAT SERVICE

(Question 1/7)

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, 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 7, 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.

RECOMMENDATION 457

USE OF THE MODIFIED JULIAN DAY BY THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICES

(Question 1/7)

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

CONSIDERING

(a) that there exist requirements for dating in a continuous sequence for various purposes in conjunction with the use of radio time signals and radio time codes;

(b) that it is desirable to refer such dating to 0000 h UT as the beginning of a day instead of 1200 h UT;

(c) that a continuing day count, the Julian Day, has long been in established use for dating in astronomy, chronology, and related sciences;

(d) that it is necessary to avoid a proliferation of different dating systems;

(e) that a simple conversion from the above-mentioned classical Julian Day to a modern continuous day count will be advantageous;

(f) that the existing established Julian Day count which refers to a Greenwich Mean Noon as the beginning of the day needs to be maintained without discontinuity;

(g) that a "Modified Julian Day" satisfying the above requirements is already in use;

UNANIMOUSLY RECOMMENDS

1. that for modern timekeeping and dating purposes, wherever required, a continuous day count, counting from 0000 h UT with five digits for day numbering be used;

2. that this “Modified Julian Day” number (MJD) be equal to the Julian Date minus 2 400 000·5;

3. that this Modified Julian Date therefore have as initial epoch 0000 h UT of 17 November 1858.

RECOMMENDATION 458

INTERNATIONAL COMPARISONS OF ATOMIC TIME SCALES

(Question 1/7)

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

CONSIDERING

(a) the need for comparisons between independent local atomic time scales of various laboratories and observatories;

(b) the need for clarity and precision in the communication of data in order to facilitate the work of the Bureau international de l’Heure (B.I.H.) in forming an international atomic scale;

UNANIMOUSLY RECOMMENDS

1. that when a laboratory or observatory “i” keeps both independent local atomic time and an approximation to coordinated universal time, designated herein as AT(i) and UTC(i), the laboratory or observatory should publish the numerical expression of the difference AT(i) — UTC(i) for each period of validity;

2. that the published time comparisons should relate to UTC(i);

3. that the published phase comparisons should relate either to AT(i) or to UTC(i) whichever is appropriate;

4. that the published times of emission of radio time signals conforming to the UTC system should relate to UTC(i);

4.1 in the case of a radio time-signal emission generated directly by the laboratory or observatory “i”, the measured delay between the time signals and UTC(i) should be published;

4.2 in the case of a radio time-signal emission controlled by a clock at the transmitting station and measured at the laboratory or observatory “i”, it should be stated explicitly whether the published times in relation to UTC(i) refer to reception or emission and what corrections for radio travel time and receiver delay should be or have been applied;

5. that any laboratories or observatories not conforming to the UTC system but desiring to take part in international comparisons and in the formation of an international atomic time scale should publish detailed data compatible, as far as possible, with the principles of §§ 1 to 4.

RECOMMENDATION 459

A NOTATION FOR REPORTING CLOCK READINGS AND FREQUENCY-GENERATOR VALUES

(Question 3/7)

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

CONSIDERING

(a) that there exists at present considerable confusion in the practices used to express time differences between clocks;

(b) that there is sometimes uncertainty as to the interpretation of reported times of reception relative to local clocks;

(c) that there also exists ambiguity in the reporting of frequency differences;

(d) that there is an urgent requirement for standardization of terminology and conventions in regard to measurements of frequency and time differences in order to avoid errors;

(e) that the International Astronomical Union (I.A.U.) in its fourth session of 29 August 1967 has adopted a Resolution concerning such conventions (Commission 31, Resolution No. 2) which helps satisfy requirements of clarity, preciseness, and usefulness for application in the field of radio time signals;

UNANIMOUSLY RECOMMENDS

1. that, to avoid any confusion in the sign of a difference in indicated time between clocks, or in frequency between frequency sources, algebraic quantities should be given;

2. that the following definitions and conventions may be used in conjunction with the algebraic expressions:

2.1 the time and location of a clock reading or a frequency measurement should always be designated;

2.2 at time T let a denote the reading of a clock A and b the reading of clock B. The difference of the readings is $a — b$ and will be conventionally designated

$$A — B = a — b \qquad (1)^*$$

2.3 let the frequency of a frequency source C be denoted by f_C and that of a frequency source D by f_D. Then the frequency difference is $f_C — f_D = \Delta f$ and may be conventionally designated as

$$C — D = \Delta f \qquad (2)$$

the nominal frequency of C and D should also be specified;

2.4 the fractional or relative frequency deviation of a frequency source C from its nominal value f_{nC} is defined as

$$F_C = (f_C / f_{nC}) — 1 \qquad (3)$$

2.5 the fractional difference in frequency between two frequency sources "H" and "K" is the difference in their fractional frequency deviations

$$S = F_H — F_K$$

and may also be designated conventionally:

$$H — K = S \qquad (4)^{**}$$

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* Example: The result of a time comparison between the portable clock, P7, and the time scale UTC of the B.I.H., measured at the B.I.H., would be reported as follows:
UTC(P7) – UTC(B.I.H.) = + 12·3 µs (7 July 1968, 14 h 35 min UTC; B.I.H.).

** Example: The result of a frequency comparison, related to the previous example, may be reported conventionally, as a relative frequency difference, as follows:
P7 – B.I.H. = $+5 \times 10^{-13}$ (7 July 1968, 14 h 35 min to 20 h 30 min UTC; B.I.H.).

2.6 a time comparison between a clock and a received time signal should follow the conventions given in §§ 2.1 and 2.2 above; a frequency comparison between an oscillator and a radio frequency emission should follow the conventions given in §§ 2.1, 2.3, 2.4 and 2.5.

RECOMMENDATION 460

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

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

CONSIDERING

(a) the desirability of eliminating all offsets from nominal values in the carrier frequencies and in the time signals;

(b) the desirability of disseminating on a world-wide basis precise time intervals in conformity with the definition of the second (SI), as adopted by the 13th General Conference of Weights and Measures (1967);

(c) the continuing need of many users for Universal Time (UT);

UNANIMOUSLY RECOMMENDS

1. that, from a specified date, carrier frequencies and time intervals should be maintained constant and should correspond to the adopted definition of the second;

2. that the transmitted time scale should be adjusted when necessary in steps of exactly one second to maintain approximate agreement with Universal Time (UT);

3. that the standard-frequency and time-signal emissions should contain information on the difference between the time signals and Universal Time (UT);

4. that detailed instructions on the implementation of this Recommendation be adopted by Study Group 7 after consideration of the report of Interim Working Party 7/1;

5. that the standard-frequency and time-signal emissions should conform to §§ 1, 2, 3 and 4 above from 1 January 1972, 0000 h UT;

6. that this document be transmitted by the Director, C.C.I.R., to all Administrations Members of the I.T.U., to the Scientific Unions (I.A.U., I.U.G.G., U.R.S.I., I.U.P.A.P.), and other organizations such as B.I.H., C.I.P.M., I.C.A.O. and I.M.C.O.

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REPORT 267-2*

STANDARD FREQUENCIES AND TIME SIGNALS

Characteristics of standard-frequency and time-signal emissions in allocated bands and characteristics of stations emitting with regular schedules with stabilized frequencies, outside of allocated bands

(1956 – 1959 – 1963 – 1966 – 1970)

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* This Report was adopted unanimously.

TABLE I

Characteristics of standard frequency and time signal emissions in the allocated bands, valid as of 1 March 1970

Station			Antenna(e)		Number of simultaneous transmissions	Period of operation		Standard frequencies used		Duration of emission		Accuracy of frequency and time intervals (parts in 10¹⁰)	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(5)	8½	2·5	1; 1000	30 in each 60	25 in each 60	±2	Steps of 100 ms
IAM(1)	Roma, Italy	41° 52′ N 12° 27′ E	Vertical λ/4	1	1	6	2	5	1; 1000 (13)	10 in each 15	4 in each 15	±0·5	Steps of 100 ms
IBF(12)	Torino, Italy	45° 02′ N 07° 46′ E	Vertical λ/4	5	1	7	2¾	5	1	continuous	nil	±0·5	Steps of 100 ms
JG2AR(1)	Tokyo, Japan	35° 42′ N 139° 31′ E	Omni-directional	3	1	5(5)	2(6)	0·02	1(7)	continuous	nil	±1	Steps 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(8)	2·5; 5; 10; 15	1(9); 1000(10)	continuous	27 in each 60	±0·5	Steps of 100 ms
LOL(1)	Buenos Aires, Argentina	34° 37′ S 58° 21′ W	Horizontal 3-wire folded dipole	2	3	7	5	5; 10; 15	1; 440; 1000	continuous	3 in each 5	±0·2	Steps of 100 ms
MSF(12)	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(1)	Praha, Czechoslovak S.R.	50° 07′ N 14° 35′ E	T	1	1	7	24	2·5	1; 1000 (11)	15 in each 30	4 in each 15	±10	Steps of 100 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(2)	5¼ hours/day(3)	±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 (4)	2 in each 5	±0·1	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	±0·5	Steps of 100 ms
WWVL(1) (14)	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	±0·1	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(12)	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 that they follow one of the systems referred to in Recommendation 374-2. As of 1 October 1969, 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 an offset from the nominal value announced for each year by the Bureau international de l'Heure.

(2) 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.

(3) From 0500 to 0807 UT at 5 MHz and from 0830 to 1207 UT at 15 MHz, excluding periods of time-signal transmissions.

(4) 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.

(5) Monday to Friday.

(6) From 0530 to 0730 UT.

(7) Interruption for 5 ms.

(8) Interrupted from 25–34 minutes of each hour.

(9) Pulse consists of 8 cycles of 1600 Hz tone. First pulse of each minute preceded by 655 ms of 600 Hz tone.

(10) 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.

(11) In the period from 1800–0600 UT, audio-frequency modulation is replaced by time signals.

(12) No offset in the carrier, coordinated time signals.

(13) 1000 Hz modulation between the minutes 1–5, 16–20, 31–35, and 45–50, except 20 ms before and after the beginning of the second; in the aforegiven minutes no time signals are radiated.

(14) WWVL is also used for synchronization tests; pertinent data are furnished by the Administration responsible.

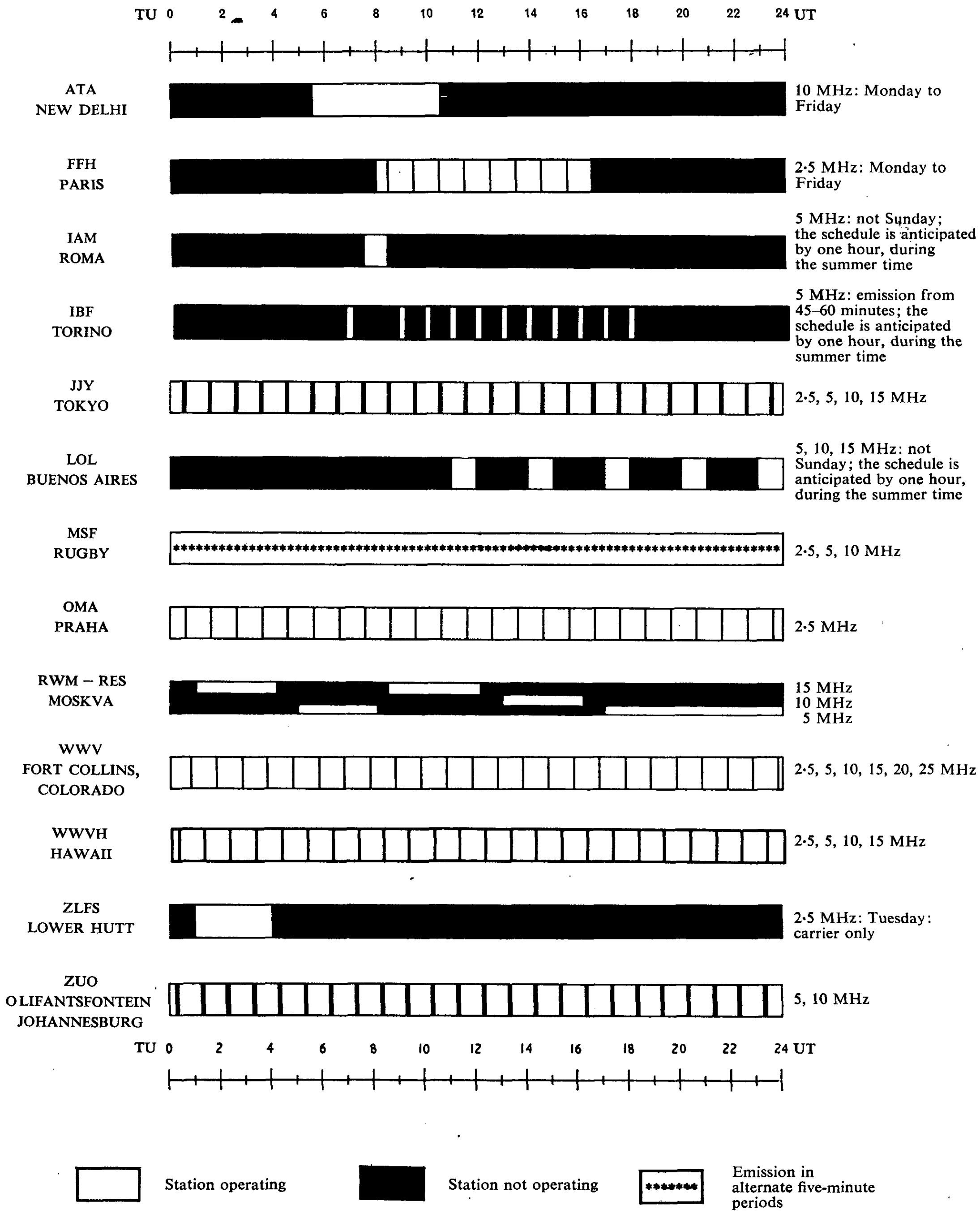
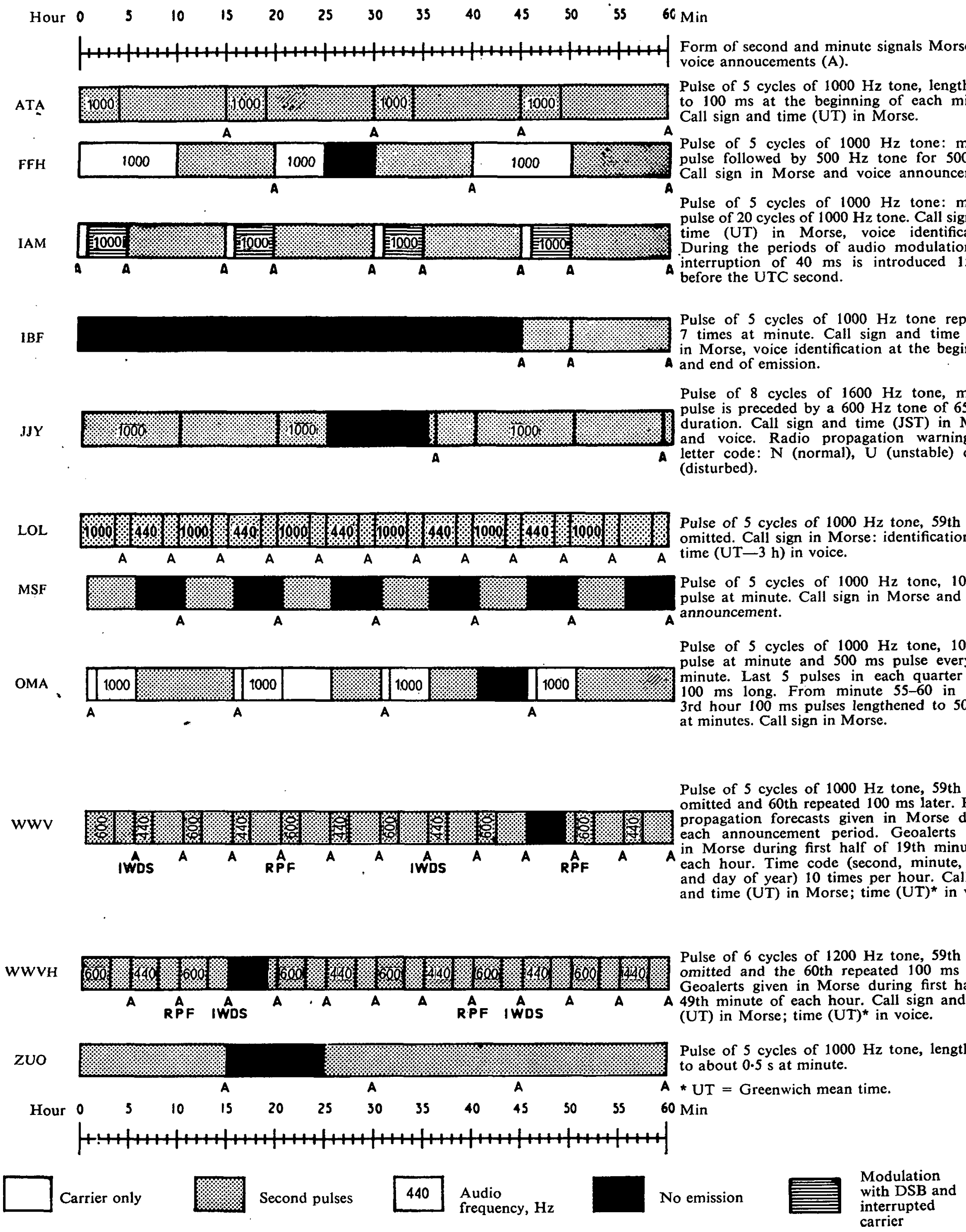


FIGURE 1

Daily emission schedule



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.

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. During the periods of audio modulation, an interruption of 40 ms is introduced 15 ms before the UTC second.

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)* 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)* in voice.

ZUO: Pulse of 5 cycles of 1000 Hz tone, lengthened to about 0·5 s at minute.

* UT = Greenwich mean time.

FIGURE 2

Hourly modulation schedule

TABLE II

Characteristics of standard-frequency and time-signal emissions in additional bands, valid as of 1 March 1970

Station			Antenna(e)		Number of simultaneous transmissions	Period of operation		Standard frequencies used		Duration of emission		Accuracy of frequency and time intervals (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)		
(27)	Allouis, France	47° 10′ N 02° 12′ E	Omni-directional	500	1	7	24	163·84(33)	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; 14670	1(4)	continuous	nil	±50	Steps of 100 ms
(27)	Donebach, F.R. of Germany	49° 34′ N 09° 11′ E	Omni-directional	70	1	7	24	151	nil	nil	continuous A3	±0·3	nil
DCF77(21)	Mainflingen, F.R. of Germany	50° 01′ N 09° 00′ E	Omni-directional	12	1	7	24	77·5	1; 440	(6) continuous	(7)	±0·1	Steps of 200 ms
(27)	Droitwich, United Kingdom	52° 16′ N 02° 09′ W	T	400	1	7	22	200	nil	nil	A3 broadcast continuously	±0·2	nil
GBR(1) (31)	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Omni-directional	750 60(2)	1	7	22(8)	15·95 16·00	1(9)	4 × 5(10) per day	nil	±0·2	Steps of 100 ms
HBG(30)	Prangins, Switzerland	46° 24′ N 06° 15′ E	Omni-directional	20	1	7	24	75	1(28)	continuous (29)	nil	±0·2	Steps of 100 ms
JJF-2 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(30)	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Omni-directional	50	1	7	24	60	1(12)	continuous	nil	±0·2	Steps of 100 ms
NAA(1) (22) (32)	Cutler, Maine U.S.A.	44° 39′ N 67° 17′ W	Omni-directional	2000 1000(2)	1	7	24	17·8	nil	nil	nil	±0·5	nil
NBA(1) (32)	Balboa, Panama Canal Zone, U.S.A.	09° 04′ N 79° 39′ W	Omni-directional	300 30(2)	1	7	24(14)	24	1(9)	continuous	nil	±0·5	Steps of 100 ms
NPG/NLK (1) (32)	Jim Creek, Washington, U.S.A.	48° 12′ N 121° 55′ W	Omni-directional	1200 250(2)	1	7	24	18·6	nil	nil	nil	±0·5	nil
NPM(1) (32)	Lualualei, Hawaii, U.S.A.	21° 25′ N 158° 09′ W	Omni-directional	1000 100(2)	1	7	24(15)	23·4	nil	nil	nil	±0·5	nil
NSS(1) (32)	Annapolis, Maryland, U.S.A.	38° 59′ N 76° 27′ W	Omni-directional	1000 100(2)	1	7	24	21·4	nil	nil	nil	±0·5	nil
NWC(1) (22) (32)	North West Cape, Australia	21° 49′ S 114° 10′ E	Omni-directional	1000(2)	1	7	24	15·5 22·3	nil	nil	nil	±0·5	nil
OMA	Podebrady, Czechoslovak S.R.	50° 08′ N 15° 08′ E	T	5	1	7	24	50	1(9)	23 hours per day(16)	nil	±10	Steps of 50 ms
RWM-RES	Moskva, U.S.S.R.	55° 45′ N 37° 18′ E		20	1	7	21(17)	100	1	40 in each 120	nil	±50	Multiples of 10 ms
SAZ(21)	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(21)	Stockholm, Sweden	59° 20′ N 18° 03′ E	Omni-directional	0·06 (ERP)	1	1 (18)	2(19)	150 000	nil	nil	10(20)	±1	nil
VNG(1)	Lyndhurst, Victoria, Australia	38° 03′ S 145° 16′ E	Omni-directional	10	2	7	24(23)	4500 7500 12000	1; 1000(24)	continuous	nil	±1	Steps of 100 ms
WWVB(21)	Fort Collins, Colorado, U.S.A.	40° 40′ N 105° 03′ W	Top-loaded vertical	13	1	7	24	60	1(3)	continuous	nil	±0·1	Steps of 200 ms
ZUO	Johannes-burg, Republic of South Africa	26° 11′ S 28° 04′ E	Omni-directional	0·05	1	7	24(26)	100 000	1	continuous	nil	±5	Steps of 100 ms

Notes to Table II

(1) These stations have indicated that they follow one of the systems referred to in Recommendation 374-2. As of 1 October 1969, 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 an offset from the nominal value announced for each year by the Bureau international de l'Heure.

(2) Figures give the estimated *radiated* power.

(3) Time code used which reduces carrier by 10 dB at the beginning of each second.

(4) Pulses of 200 cycles of 1000 Hz tone: the first pulse in each minute is prolonged.

(5) Maintenance period from 0400 to 0800 UT on the second Thursday of each month.

(6) Al time signals (interruptions of the carrier during 100 ms at the beginning of each second except for the second No. 59 of each minute) from the Physikalisch-Technische Bundesanstalt.

(7) Call sign is given by modulation of the carrier with 440 Hz tone three times every hour at the minutes 19, 39 and 59.

(8) Maintenance period from 1300 to 1430 UT each day.

(9) Al telegraphy signals.

(10) From 0255 to 0300, 0855 to 0900, 1455 to 1500 and 2055 to 2100 UT.

(11) Maintenance period from 1300 to 1600 UT on the first Sunday of each month.

(12) 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.

(13) Time pulses occur in groups of 8, one millisecond apart; 20 groups per second.

(14) Except from 1300 to 2100 UT on Wednesday.

(15) Except from 1800 to 2300 UT on Wednesday.

(16) From 1000 to 1100 UT, transmission without keying except for call-sign OMA at the beginning of each quarter-hour.

(17) 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.

(18) Each Friday.

(19) From 0930 to 1130 UT.

(20) 5 minutes at the beginning and 5 minutes at the end of the transmission for identification purposes only.

(21) No offset, either on carrier or on time signals.

(22) 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

(23) 4500 kHz, from 0945 UT to 2130 UT, 12 000 kHz, from 2145 UT to 0930 UT, 7500 kHz, continuous service, with a technical interruption from 2230 UT to 2245 UT.

(24) Pulses of 50 cycles of 1000 Hz tone, shortened to 5 cycles from the 55th to the 58th second; the 59th pulse is omitted. At the 5th, 10th, 15th, etc. minutes, pulses from the 50th to the 58th second are shortened to 5 cycles; voice identification between the 20th and 50th pulses in the 15th, 30th, 45th and 60 minutes.

(25) Except first minute of each hour.

(26) No transmissions between 15 and 25 minutes past each hour.

(27) Carrier without offset.

(28) Interruption of the carrier during 100 ms at the beginning of each second; double pulse each minute; triple pulse each hour; quadruple pulse each 12 hours.

(29) In absence of telegraph traffic.

(30) Experimental emission; no offset in the carrier, coordinated time signals.

(31) FSK is used, alternatively with CW; both carriers are frequency controlled.

(32) This station is primarily for communication purposes; while these data are subject to change, the changes are announced in advance to interested users by the U.S. Naval Observatory, Washington, D.C., U.S.A.

(33) Temporary.

TABLE III

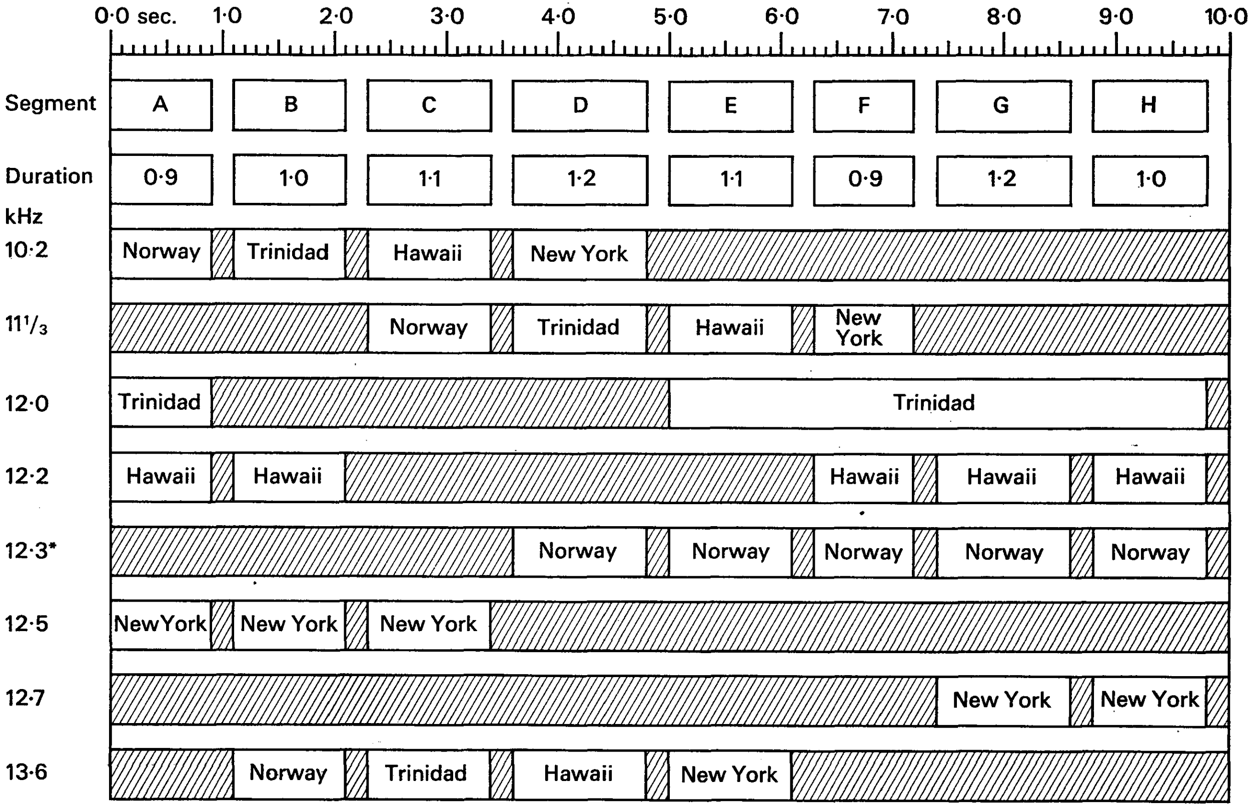
Characteristics of some navigational aids, valid as of 1 March 1970

Station			Antenna(e)		Number of simultaneous transmissions	Period of operation		Standard frequencies used		Duration of emission		Accuracy of frequency and time intervals (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)	Pulses/s	Time signal	Audio-modulation		
Loran-C SS7-M	Carolina Beach N.C. U.S.A.	34°03′46″N 77°54′46″W	Omni-directional	800(4)	1	7	24	100	(1) 99·300(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS7-W	Jupiter, Florida, U.S.A.	27°01′59″N 80°06′53″W	Omni-directional	400(4)	1	7	24	100	(1) 99·300(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS7-X	Cape Race, Newfoundland	46°46′32″N 53°10′29″W	Omni-directional	3000(4)	1	7	24	100	(1) 99·300(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS7-Y	Nantucket Island, U.S.A.	41°15′12″N 69°58′39″W	Omni-directional	400(4)	1	7	24	100	(1) 99·300(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS7-Z	Dana, Indiana, U.S.A.	39°51′08″N 87°29′11″W	Omni-directional	400(4)	1	7	24	100	(1) 99·300(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SL3-M	Ejde, Faroe Is.	62°17′57″N 7°04′15″W	Omni-directional	400(4)	1	7	24	100	(1) 79·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SL3-W	Sylt, Germany	54°48′29″N 8°17′41″E	Omni-directional	300(4)	1	7	24	100	(1) 79·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SL3-X	Bo, Norway	68°38′05″N 14°27′54″E	Omni-directional	200(4)	1	7	24	100	(1) 79·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SL3-Y	Sandur, Iceland	64°54′31″N 23°55′08″W	Omni-directional	3000(4)	1	7	24	100	(1) 79·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SL3-Z	Jan Mayen, Norway	70°54′56″N 8°43′59″W	Omni-directional	200(4)	1	7	24	100	(1) 79·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SH4-M	Johnston Is.	16°44′44″N 169°30′32″W	Omni-directional	300(4)	1	7	24	100	(1) 59·600(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SH4-X	Upolo Pt., Hawaii	20°14′50″N 155°53′09″W	Omni-directional	300(4)	1	7	24	100	(1) 59·600(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SH4-Y	Kure, Midway Is.	28°23′41″N 178°17′30″W	Omni-directional	300(4)	1	7	24	100	(1) 59·600(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS3-M	Iwo Jima, Japan	24°48′04″N 141°19′29″E	Omni-directional	4000(4)	1	7	24	100	(1) 99·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS3-W	Marcus Is.	24°17′08″N 153°58′51″E	Omni-directional	4000(4)	1	7	24	100	(1) 99·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS3-X	Hokkaido, Japan	42°44′33″N 143°43′05″E	Omni-directional	400(4)	1	7	24	100	(1) 99·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS3-Y	Gesashi, Okinawa	26°36′21″N 128°08′54″E	Omni-directional	400(4)	1	7	24	100	(1) 99·700(5)	continuous	nil	±0·05	Steps of 1 μs
Loran-C SS3-Z	Yap, Caroline Is.	9°32′46″N 138°09′55″E	Omni-directional	4000(4)	1	7	24	100	(1) 99·700(5)	continuous	nil	±0·05	Steps of 1 μs
OMEGA Ω/N	Aldra, Norway	66°25′N 13°09′E	Omni-directional	4(2)	1	7	24	10·2-A(3) $11^1/_3$-C 13·6-B	nil	(3)	nil	±0·5	
OMEGA Ω/NY	Forestport, N.Y., U.S.A.	43°27′N 75°05′W	Omni-directional	0·25(2)	1	7	24	10·2-D(3) $11^1/_3$-F 12·5-A, B, C 12·6-G, H 13·6-E	nil	(3)	nil	±0·5	
OMEGA Ω/T	Trinidad, West Indies	10°42′N 31°38′W	Omni-directional	1(2)	1	7	24	12·0-A, E, F, G, H $11^1/_3$-D 13·6-C(3) 10·2-B	nil	(3)	nil	±0·5	
OMEGA Ω/H	Haiku, Hawaii, U.S.A.	21°24′N 157°50′W	Omni-directional	2(2)	1	7	24	10·2-C(3) $11^1/_3$-E 13·6-D	nil	(3)	nil	±0·5	

(1) Time pulses appear in groups of 9 for the master station (M) and groups of 8 for the slave stations (W, X, Y, Z).
(2) Figures give the estimated radiated power.
(3) See Table IV.
(4) Peak radiated power.
(5 Pulse repetition period in microseconds.

TABLE IV

OMEGA signal format



Segment	A	B	C	D	E	F	G	H
Duration	0·9	1·0	1·1	1·2	1·1	0·9	1·2	1·0
kHz								
10·2	Norway	Trinidad	Hawaii	New York	▨	▨	▨	▨
11¹/₃	▨	▨	Norway	Trinidad	Hawaii	New York	▨	▨
12·0	Trinidad	▨	▨	▨	Trinidad			
12·2	Hawaii	Hawaii	▨	▨	▨	Hawaii	Hawaii	Hawaii
12·3*	▨	▨	▨	Norway	Norway	Norway	Norway	Norway
12·5	NewYork	New York	New York	▨	▨	▨	▨	▨
12·7	▨	▨	▨	▨	▨	▨	New York	New York
13·6	▨	Norway	Trinidad	Hawaii	New York	▨	▨	▨

* Transmissions on unique frequency from Norway have started for testing purposes.

Note 1.— Carrier frequencies are offset according to the B.I.H.

Note 2.— The OMEGA stations are primarily for navigation purposes; while these data are subject to change, the changes are announced in advance to interested users by the U.S. Naval Observatory, Washington D.C., U.S.A.

REPORT 269-2*

REDUCTION OF MUTUAL INTERFERENCE BETWEEN STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

(1963 - 1966 - 1970)

The appreciable amount of mutual interference between standard-frequency and time-signal emissions continues to detract from the value of the services operating in the allocated bands. 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 transmitters and being received in an area where the various signals arrive within intervals of only 2 ms or less. The position in Western Europe on 5 MHz where this applies, has been improved by the decision of IAM, IBF and MSF to coordinate their respective transmission programmes. On 2·5 MHz, on the other hand, the situation has not been improved by the increase in radiated power of Station FFH which can interfere strongly at certain times with the other stations on this frequency, MSF and OMA.

The emissions of time signals in band 5 (DCF on 77·5 kHz, HBG on 75 kHz, MSF on 60 kHz and OMA on 50 kHz) offer a means of circumventing the difficulties of reception in band 7 by providing an alternative source of time signals.

The use of continuous audio-frequency tone modulation in a number of emissions is a common source of interference with time-signal reception. Audio-frequency tone modulation is essentially confined to uses which do not require high accuracy, and it appears desirable to restrict the use of this type of modulation. IBF and MSF have already eliminated audio-frequency tone-modulation periods from their programmes; OMA has replaced audio-frequency tone-modulation by time signals during the period from 1800 to 0600 h UT. IAM (5 MHz) has reduced the number of audio-frequencies used from three to one (1000 Hz) and a total period of modulation from 40 to 16 minutes per hour. Station LOL has reduced the total period of audio-frequency tone modulation from 44 to 33 minutes in each hour.

Other possible solutions to the problem of the coexistence of several time and frequency stations are under study. During recent years, for instance, WWV and WWVH, in addition to reducing the time allotted to audio-frequency tone modulation have introduced a break of 40 ms in the continuous modulation during which time signals are emitted. This technique has also been employed in Japan by JJY where the length of the break in modulation has been extended to 85 ms to enable time signals to be received from other synchronized stations 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. IAM has also introduced a 40 ms break in transmission to facilitate the reception of time signals from other stations.

Mutual interference between MSF-60 kHz and WWVB-60 kHz has been occasionally noticed in the eastern part of the United States of America [1]. It is particularly severe during afternoon and evening hours. Interference was aggravated by the recent removal of the offset in the MSF carrier because it reduced the chance of identification. Further complications may

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* This Report was adopted unanimously.

arise after the execution of announced plans to increase the MSF power output. Other occasional interference has been experienced with stations in band 4 [1, 2].

Although the Plenary Assemblies of the C.C.I.R. provide the opportunity for useful discussions between Administrations, it should 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 of Study Group 7, 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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REPORT 270-2*

FREQUENCY SPECTRUM CONSERVATION FOR HIGH-PRECISION TIME SIGNALS

(Study Programme 3A-1/7)

(1963 - 1966 - 1970)

There is an increasing number of applications requiring the use of a very precise reference for time-signal synchronization. In an effort to achieve greater precision, it is desirable to make use of a suitable bandwidth up to the limits imposed by:

— the band allocated;

— the instabilities of the propagation;

— considerations of noise and interference.

A system developed to exploit the characteristics of ground-wave propagation is the navigational system known as LORAN-C operating at 100 kHz. The modulation is chosen 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 is limited to a total bandwidth of ± 10 kHz.

The East Coast (of North America), Norwegian Sea, Central Pacific and Northwest Pacific LORAN-C chains have been synchronized to UTC such that the start of the first pulse in each group of pulses emitted by the master stations in these chains is periodically coincident with the UTC second. This is accomplished to an accuracy of ± 5 μs. In addition, a one-pulse-per-second transmission is made from the master stations of synchronized chains to enable the less complicated visual reception technique to be used.

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* This Report was adopted unanimously.

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 Table I (Report 267-2) that all stations, with the exception of HBN and RWM-RES, use an audio-frequency modulation as the time signal. This takes the form previously recommended by C.C.I.R., and consists of *n* cycles of 200 *n* Hz audio 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 adopted a pulse waveform with $n = 5$, i.e., 5 cycles at 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 one of the several components of a signal received via more than one path (multi-path propagation). It is, however, reasonably economical in bandwidth. Disturbed propagation conditions produce easily recognizable distortions of the pulse waveform.

A method of signal dissemination which does not require the use of excessive bandwidth has been investigated for use in navigation [1] and timing [2]. This method makes use of the interference between two closely-spaced phase.coherent carrier frequencies to generate a coarse reference. When this coarse reference can be realized at the receiver with sufficient phase stability it serves to identify one particular cycle of the carrier frequencies and a precise time reference can then be obtained from observations of the carrier phase.

Early experiments using 19·9 and 20·0 kHz over a 1400 km path showed promise for cycle identification. Later experimental studies, including a technique for extracting time using conventional VLF receivers and giving results covering a period of months over a 2400 km path have been reported [3]. Further studies using several frequency separations and paths have been described [4]. An experimental dual frequency timing receiver has been constructed for use with the 20·0 and 19·9 kHz transmissions of WWVL [5]. The result of these various investigations suggested that a 100 Hz frequency difference between the carrier frequencies is too small to permit reliable daily cycle identification over arbitrary paths and in a further series of experiments a third carrier frequency was added to the WWVL emission to give frequency differences of 500 and 600 Hz. The results obtained under these conditions are now being evaluated but appear to indicate that, with suitable averaging, cycle identification can be achieved at distances up to 8000 km. An analytical study using information theory techniques indicates that a multiple CW system may be optimum from the bandwidth conservation viewpoint [6]. Reference [7] has a useful bibliography on the general subject.

Theoretical studies are being made on a similar, very narrow bandwidth system at VLF [8]. Two procedures are being investigated. The first uses 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. This procedure takes advantage of the timing index given by phase modulation of the radio frequency signal [9] (not of the envelope). The second procedure uses periodic phase inversions of the carrier wave; the cases where inversions occur at zero phase and $\pi/2$ phase have been treated in detail [10]. This reference also presents the results of calculations giving the relation between time discrimination and the bandwidth of the system. The theoretical results obtained are promising and instrumental developments are proceeding [11].

A system using multiple carriers at VLF has also been proposed [12] which enables the transmission of both 1 s and 10 ms time signals without interruption to the communication service. A theoretical description of the transmissions with three frequencies and of the receiving devices is given in the reference.

There is a limit to the timing accuracy which can be achieved by using two or more closely spaced signals. The limitation arises because the group delay T of the composite signal is given by

$$T = (\varphi_2 - \varphi_1) / 2\pi (f_2 - f_1)$$

where φ_1 and φ_2 are the phase delays experienced by the two frequencies f_1 and f_2. The variation in the phase delays due to propagation can be expected to approach zero as $(f_2 - f_1)$ approaches zero. However, the effect of additive noise is essentially independent of the frequency spacing. Under these conditions the standard deviation of the group delay σ_T is given by [2]

$$\sigma_T = (\sqrt{2}\, \sigma_\varphi) / 2\pi (f_2 - f_1)$$

where $\sigma_\varphi = \sigma_{\varphi_1} = \sigma_{\varphi_2}$ is the standard deviation of the phase delays due to additive noise. As an example, if $\sigma_\varphi = 1$ µs and $f_1 = 20$ kHz while $f_2 = 20\,001$ Hz, $\sigma_T = 20\,000$ µs; whereas, if $f_2 = 20\,100$ Hz, $\sigma_T = 200$ µs. Thus, as the spacing of the frequencies decreases, the error due to uncorrelated phase fluctuations increases.

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REPORT 271-2*

STABILITY AND ACCURACY OF STANDARD FREQUENCY AND TIME SIGNALS AS RECEIVED

(Question 3/7)

(1963 – 1966 – 1970)

1. Stability of standard frequency and time signals in the VLF and LF bands (bands 4 and 5)

Several reports have been presented on the propagation of VLF signals [2, 3, 4, 5, 7, 8, 9, 10]. The phase of the received signals undergoes both diurnal and seasonal changes 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 or at the same part of the diurnal phase variation curve for each day.

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. The "cycle loss" can occur in several circumstances. In one case it will occur when the ratio of the amplitudes of the first to second order waveguide modes is less than unity at night and greater than unity during the day [11]. A second case may occur because of excessively large mode conversion at the sunrise termination [12]. In addition, when the receiver is at a great distance ($>$ 10 000 km) from the transmitter, it is possible that signals may be received along the long great circle path instead of the short great circle path for part of the day [4]. If the stability 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, the signals of NBA and NPM in France, and WWVL in England.

The effects of dispersion which cause the phase and group velocities of VLF and LF waves to be different must be considered in timing systems. At LF, appreciable dispersion occurs in the ground wave for propagation over ground of finite conductivity. At VLF, two sources of dispersion are important. The first arises because of cut-off effects in the Earth-ionosphere waveguide [13]. The second [14] and less predictable source of dispersion is caused by interference between several waveguide modes at night and thus causes spatially periodic variations in group velocity.

The time service provided by the transmitter HBG on 75 kHz located near Geneva (see Report 267-2, Table II) reaches a large part of Central Europe. Experiments have shown that the time signal of HBG can be received using simple receivers with an accuracy better than ± 50 μs at medium distances (100 - 1000 km) [15]. The phase of the carrier is typically stable to better than ± 2 μs at the distance of 500 km during daylight hours.

As regards the long-term integration of the received phase, the accuracy which can be achieved will depend to a large extent on the complexity of the receiving equipment and measuring procedures. It has been reported [18, 19] that when using quartz oscillators at the receiving station the accumulated overall error for path lengths of 1000 to 5000 km, is between 25 and 50 μs per year when receiving transmissions in bands 4 and 5. However, when the received phase is referred to an atomic standard and use is made of a receiver which can be calibrated and which does not lose the phase reference [22] then much improved results can be obtained. Thus, NSS received at a distance of 5000 km and recorded over a period in excess of 450 days shows variations relative to the mean phase of at most ± 10 μs and generally

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* This Report was adopted unanimously.

REPORT 271-3*

STABILITY AND ACCURACY OF STANDARD FREQUENCY AND TIME SIGNALS AS RECEIVED

(Question 3/7)

(1963 – 1966 – 1970 – 1971)

1. Stability of standard frequency and time signals in the VLF and LF bands (bands 4 and 5)

Several reports have been presented on the propagation of VLF signals [2, 3, 4, 5, 7, 8, 9, 10]. The phase of the received signals undergoes both diurnal and seasonal changes 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 or at the same part of the diurnal phase variation curve for each day.

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. The "cycle loss" can occur in several circumstances. In one case, it will occur when the ratio of the amplitudes of the first to second order waveguide modes is less than unity at night and greater than unity during the day [11]. A second case may occur because of excessively large mode conversion at the sunrise termination [12]. In addition, when the receiver is at a great distance ($>$ 10000 km) from the transmitter, it is possible that signals may be received along the long great circle path instead of the short great circle path for part of the day [4]. If the stability 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, the signals of NBA and NPM in France, and WWVL in the British Isles.

The effects of dispersion which cause the phase and group velocities of VLF and LF waves to be different must be considered in timing systems. At LF, appreciable dispersion occurs in the ground wave for propagation over ground of finite conductivity. At VLF, two sources of dispersion are important. The first arises because of cut-off effects in the Earth-ionosphere waveguide [13]. The second [14] and less predictable source of dispersion is caused by interference between several waveguide modes at night and thus causes spatially periodic variations in group velocity.

The time service provided by the transmitter HBG on 75 kHz located near Geneva (see Report 267-2, Table II) reaches a large part of Central Europe. Experiments have shown that the time signal of HBG can be received using simple receivers with an accuracy better than $\pm$ 50 μs at medium distances (100-1000 km) [15]. The phase of the carrier is typically stable to better than $\pm$ 2 μs at the distance of 500 km during daylight hours.

Experiments on the propagation of LF (40 kHz) signals at a distance of 400 km have been reported by Japan [25]. The standard deviation of the daily phase fluctuations was found to be 1 μs in summer and 2 μs in winter: the seasonal variation in the phase of the signal as received at midday amounted to 3·3 μs.

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* This Report was adopted unanimously.

less than ± 3 μs. This latter figure is equivalent to a frequency uncertainty of about 1×10^{-13} over a year. Further improvements in the stability of the received phase can be obtained by forming a linear combination of the phase of two emissions at different frequencies to reduce significantly the major solar effects; the improvement is most noticeable when comparisons are made simultaneously for both directions of transmission over the same path at carrier frequencies not too far separated in band 4. Still greater accuracy in the phase reference can be obtained by the application of smoothing techniques based on the statistical character of the phase fluctuations [22, 23] but these are effective only over limited periods where the statistical behaviour can be assumed representative of the process.

2. Stability of time signals in bands 6 and 7, as received

The results of time-signal comparisons carried out in Italy [16] and Japan [21] in the years 1961-1968, have been reported. When using a comparison system whose accuracy was ± 0·01 ms, the standard deviation for a single reception has been found to vary from 0·01 ms at a distance of a few kilometres to about 0·5 ms at distances of about 18 000 km. For intermediate distances the standard deviation ranged from 0·015 ms at 500 km to 0·1 ms at 1000 km. Most signals have been found to exhibit little seasonal variation except those from WWV and IAM when reception becomes poor in the northern hemisphere winter.

3. Stability of standard frequency time signals in bands 8 and 9, as received

New techniques have been brought into use in the Czechoslovak Socialist Republic [20], making use of the frame synchronizing pulses in normal television transmissions and precise time reference. By simultaneous measurements of these pulses, two remote clocks have been related to an accuracy of 2 μs over a distance of 300 km. This proposed, also, to synchronize the frame pulse generator to a standard time source.

Measurements have been made in Italy in bands 8 and 9 to determine the causes of reduced stability and accuracy in time signals as received and to establish the statistical distribution of the instability values.

The results show that, when using non-specialized equipment, the standard deviation of time signals distributed by radio broadcast networks and radio links is less than 0·4 ms, over about 1500 km [17, 24].

For radio-relay links in band 9, the standard deviation of frequency measurements is several parts in 10^9, as determined by three consecutive measurements of 1000 s duration, again using non-specialized equipment.

In the Federal Republic of Germany, precise frequency control has been extended to ten television stations operating in the frequency range 471·24 to 599·26 MHz. The transmitter frequencies are adjusted relative to a central standard frequency source and the six stations examined showed a frequency deviation of less than 1 part in 10^{10}. The signals received at distances of 46 to 125 km from the transmitter were found to have phase fluctuations in a 30 s period corresponding to frequency variations of about 1×10^{-11}, in the worst case.

4. Stability over a line-of-sight microwave link (band 10)

Experiments have been made [1] on the instability introduced by propagation over a 50 km line-of-sight microwave 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.

As regards the long-term integration of the received phase, the accuracy which can be achieved will depend to a large extent on the complexity of the receiving equipment and measuring procedures. It has been reported [18, 19] that when using quartz oscillators at the receiving station the accumulated overall error for path lengths of 1000 to 5000 km, is between 25 and 50 μs per year when receiving transmissions in bands 4 and 5. However, when the received phase is referred to an atomic standard and use is made of a receiver which can be calibrated and which does not lose the phase reference [22] then much improved results can be obtained. Thus, NSS received at a distance of 5000 km and recorded over a period in excess of 450 days shows variations relative to the mean phase of at most ± 10 μs and generally less than ± 3 μs. This latter figure is equivalent to a frequency uncertainty of about 1×10^{-13} over a year. Further improvements in the stability of the received phase can be obtained by forming a linear combination of the phase of two emissions at different frequencies to reduce significantly the major solar effects; the improvement is most noticeable when comparisons are made simultaneously for both directions of transmission over the same path at carrier frequencies not too far separated in band 4. Still greater accuracy in the phase reference can be obtained by the application of smoothing techniques based on the statistical character of the phase fluctuations [22, 23] but these are effective only over limited periods where the statistical behaviour can be assumed representative of the process.

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Further Japanese results have been obtained in 1969-70 making use of photographic integration of the received time signal phase [25]. They indicate that signals propagating via the night-time E- or E_s-layer are received at distances of 400 and 1100 km with a stability (1σ) of 6 μs on 2·5 MHz and 14 μs on 5 MHz. The propagation time on 5 MHz at a distance of 400 km was found to vary by approximately 55 μs during the year owing to the seasonal changes in the E-layer critical frequency.

3. Stability of standard frequency and time signals in bands 8 and 9, as received

New techniques have been brought into use in the Czechoslovak Socialist Republic [20], making use of the frame synchronizing pulses in normal television transmissions and precise time reference. By simultaneous measurements of these pulses, two remote clocks have been related to an accuracy of 2 μs over a distance of 300 km. It is proposed, also, to synchronize the frame pulse generator to a standard time source.

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The results show that, when using non-specialized equipment, the standard deviation of time signals distributed by radio broadcast networks and radio-relay links is less than 0·4 ms, over about 1500 km [17, 24].

For radio-relay links in band 9, the standard deviation of frequency measurements is several parts in 10^9, as determined by three consecutive measurements of 1000 s duration, again using non-specialized equipment.

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 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.

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REPORT 362-1*

OPERATION WITH VARIOUS COMBINATIONS OF CARRIER AND SIDEBANDS FOR THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICE

(Study Programme 1B-1/7)

(1966 - 1970)

Single-sideband operation with full carrier (A3H) is a class of emission that has been shown in some studies [1] to be effective in 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 had been transmitting 440 Hz and 600 Hz tone frequencies using the standard frequency carriers of 2·5, 5·0, 10·0, 15·0 and 20·0 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 tone frequency transmissions to justify the equipment necessary to continue the service. Conventional double-sideband tone frequency transmissions were commenced on 1 March 1965.

Station WWV has been rebuilt and relocated and is now capable of single-sideband operation with either sideband and any degree of carrier insertion. Plans exist to rebuild station WWVH possessing the same modulation capabilities as WWV. If found desirable, it would then be possible to operate WWV on the upper sideband and WWVH on the 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.

Stations in the U.S.S.R., using frequencies in band 7, are also making experimental transmissions of standard frequencies and time signals using both single sideband with full carrier and also double sideband with suppressed carrier.

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* This Report was adopted unanimously.

REPORT 363-1*

INTERCOMPARISONS OF TIME SCALES BY VARIOUS METHODS

(Study Programme 3C-1/7)

(1966 - 1970)

Numerous intercomparisons of time scales associated with standard-frequency generators have been made in recent years. Some of these have been made using radio signals [1, 2, 3, 4, 5, 6]. With respect to phase comparisons in bands 4 and 5, it is suggested [7] that the receivers should be calibrated as a precaution against displacement and phase loss, and that each laboratory should determine the best moment of the day for phase reading. In these conditions, time scales can be compared to an accuracy of a few microseconds without introducing cumulative errors. Additional reduction of phase uncertainty can be achieved by means of appropriate smoothing techniques [8, 9]. Television synchronization pulses have been used as time markers; for short distances, an accuracy of some tens of nanoseconds was attained, while for long distances errors were less than 1 μs [10, 11]. Since synchronization of the LORAN-C Atlantic chains (August, 1968), a few European and American laboratories have been connected with an accuracy within 0·2 μs by the reception of LORAN-C pulses. The intercomparison of time scales by using a transportable clock has come into general use. This is the most accurate method used for calibrating propagation time and instrument delay when required (for example, for the receivers of LORAN-C or television signals). An improvement of this method consists in synchronization by flying clocks without landing [12], in which case an accuracy of some tens of nanoseconds is possible.

The results of these intercomparisons have enabled several studies to be made to determine the optimum method of forming a mean atomic time scale on a local or international basis [6, 13]. With LORAN-C receivers, it has been possible to improve the B.I.H. international atomic time scale [14].

Three clock synchronization experiments have been performed using two-way transmission of timing signals relayed by artificial satellites. The Telstar-I transponder, operating in band 10, was used between the United States of America and the United Kingdom in August 1962, and an accuracy of 1 μs was achieved [15]. Comparisons between the United States of America and Japan were made in bands 9 and 10 in February 1965 using Relay II and employing the method of retransmission of pulses [16, 17]. An accuracy of synchronization 0·1 μs was estimated. A VHF comparison between Colorado California, and Hawaii was made in June 1967 using ATS-1 with an accuracy of 5 μs [18].

Time transfer using one-way VHF transmissions relayed by a geostationary satellite (ATS-1) between Colorado, California, and Alaska was investigated in November 1967 [19]. Accuracies of 10 μs were observed.

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* This Report was adopted unanimously.

REPORT 363-2*

INTERCOMPARISONS OF TIME SCALES BY VARIOUS METHODS

(Study Programme 3C-1/7)

(1966 - 1970 - 1971)

Numerous intercomparisons of time scales associated with standard-frequency generators have been made in recent years. Some of these have been made using radio signals [1, 2, 3, 4, 5, 6]. With respect to phase comparisons in bands 4 and 5, it is suggested [7] that the receivers should be calibrated as a precaution against displacement and phase loss, and that each laboratory should determine the best moment of the day for phase reading. In these conditions, time scales can be compared to an accuracy of a few microseconds without introducing cumulative errors. Additional reduction of phase uncertainty can be achieved by means of appropriate smoothing techniques [8, 9]. Television synchronization pulses have been used as time markers; for short distances, an accuracy of some tens of nanoseconds was attained, while for long distances errors were less than 1 µs [10, 11, 20]. For long-term comparison at extended distances, the stability of propagation delay in the radio links in the networks is of importance. Studies in Italy [21] have shown variations of 3 µs over a period of 100 days relative to an alternative path of 740 km long in coaxial cable. Since synchronization of the LORAN-C Atlantic chains (August, 1968), a few European and American laboratories have been connected with an accuracy within 0·2 µs by the reception of LORAN-C pulses. Extension of LORAN-C synchronization to the Pacific area has enabled time comparisons to be made between the UTC scale of the Radio Research Laboratories, Tokyo and the corresponding scale of the U.S. Naval Observatory. Using the LORAN-C signals from Iwo-Jima and also a USNO portable clock, an uncertainty of 0·5 µs (1σ) was achieved [22].

The intercomparison of time scales by using a transportable clock has come into general use. This is the most accurate method used for calibrating propagation time and instrument delay when such calibrations are required (for example, for the receivers of LORAN-C or television signals). An improvement in the method consists in synchronization by means of airborne clocks overflying observatories or laboratories without the necessity of landing [12]. The first experiments between the Paris Observatory and the Physikalisch-Technische-Bundesanstalt, Braunschweig, have been followed by an operation across the Atlantic between the observatories of Paris, Greenwich and Washington, the National Research Council, Ottawa, and with the participation of the Bureau international de l'Heure [23]. The precision achieved in this experiment was of the order of a few tens of nanoseconds.

The results of these intercomparisons have enabled several studies to be made to determine the optimum method of forming a mean atomic time scale on a local or international basis [6, 13]. With LORAN-C receivers, it has been possible to improve the B.I.H. international atomic time scale [14].

Three clock synchronization experiments have been performed using two-way transmission of timing signals relayed by artificial satellites. The Telstar-I transponder, operating in band 10, was used between the United States of America and the United Kingdom in August 1962, and an accuracy of 1 µs was achieved [15]. Comparisons between the United States of America and Japan were made in bands 9 and 10 in February 1965 using Relay II and employing the method of retransmission of pulses [16, 17]. An accuracy of synchronization 0·1 µs was estimated. A VHF comparison between Colorado California, and Hawaii was made in June 1967 using ATS-1 with an accuracy of 5 µs [18].

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* This Report was adopted unanimously.

Time transfer using one-way VHF transmissions relayed by a geostationary satellite (ATS-1) between Colorado, California, and Alaska was investigated in November 1967 [19]. Accuracies of 10 μs were observed.

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REPORT 364-1*

INSTABILITY OF STANDARD-FREQUENCY GENERATORS

(Study Programme 3B/7)

(1966 - 1970)

In recent years, the results of a large number of studies have become available concerning the instability of standard-frequency generators. Theoretical treatments of the problem, definitions and experimental procedures for measurement have been widely investigated. With the increased demands for both long- and short-term stability for various applications it is inevitable that this subject will remain of interest and importance for some years to come.

It has been shown [1, 2, 3] that the type of noise present in a standard-frequency generator may be classified by the form of the frequency (or phase) spectral density which it produces. Suitable mathematical techniques have been devised for operating on these functions or on their related Fourier transforms, the auto-correlation functions [4, 5]. The effect of the so-called "flicker noise" having a $1/f$ spectral variation is particularly important in the long-term operation of all forms of frequency standard and special studies have been devoted to this aspect [6].

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* This Report was adopted unanimously.

In both atomic sources and in quartz crystal oscillators, thermal and shot noise will contribute to the short-term instability and, depending upon the mechanism, will produce either a flat or a $1/f^2$ variation in the frequency spectral density. The intended use of the standard-frequency generator will determine the importance of these effects relative to the instability produced by flicker noise.

Thus, the hydrogen maser is the preferred frequency reference for use at radio astronomy observatories engaged in long-baseline interferometry as the maser provides the greatest degree of phase coherence over the periods of 10^3 to 10^4 seconds occupied by the observations. For longer periods, greater than 10^5 to 10^6 seconds, a well developed caesium standard would be expected to generate a more stable reference, while for shorter intervals, less than 10 seconds, the frequency stability of a high quality quartz oscillator has been shown [7] to be superior to that of quantum devices, which are all subject to a shot-noise limitation.

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REPORT 366-1*

PROPERTIES OF SYSTEMS WHICH YIELD TIME AND FREQUENCY INFORMATION FROM RADIO EMISSION

(Study Programme 1C-1/7)

(1966 – 1970)

1. Introduction

Study Programme 1C-1/7 decides that studies and experiments should be made to provide both UT and AT in the same emissions. The present document calls attention to some definitions of terms useful for describing time and frequency information emission systems chosen for study [1].

2. Definitions

2.1 By *carrier offset* is meant an intentional fractional frequency deviation from the nominal carrier frequency value.

2.2 A *marker* is a reference signal or other event often repeated periodically at a specified frequency to enable one to assign numerical values to specific events in a time scale.

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* This Report was adopted unanimously.

2.3 By *marker frequency offset* of emitted time signals is meant an intentional fractional deviation of the rate of occurrence of the marker from its nominal value, usually one marker per second.

2.4 By a *time step* is meant an intentional discontinuity introduced at some instant in an otherwise uniform sequence of time intervals. A time step is positive (+) if the clock reading is increased, and negative (–) if it is decreased by making the step.

2.5 A *time scale* is defined either by its initial event and a scale measure (e.g. the second) or a sequence of events. Some time scales are based upon clocks and some also upon astronomical phenomena. For the purpose of making precise time readings of a time scale, and to enable the distribution of a scale by electromagnetic means, a sequence of signals (or markers) is widely used representing special scale values.

2.6 Time scales belonging to time systems such as UTC or SAT are said to be *coordinated* by the use of well-defined synchronization, dissemination, publication, and correction procedures.

2.7 A clock in a set of clocks distributed over a spatial region and which are synchronized to a reference clock *at a specified location (spatial origin)* is called a *coordinate clock.*

2.8 A time scale is called a *coordinate* time scale if it is disseminated over a spatial region with varying gravitational potentials by some well-defined procedure, so that two spatially separated events are considered to be simultaneous if the coordinate clocks at the events are synchronized by this procedure and have the same reading.

2.9 Any *reading* of a clock or time scale should be denoted by giving the time-scale name followed, in parentheses, by the clock name, transmitting station, astronomical observatory, or standards laboratory such as:

UTC	(Clock number 8)
AT	(B.I.H.)
UTO	(Tokyo)
SAT	(DCF77)

The date of a specific reading should be given with its value.

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REPORT 438*

HIGH PRECISION STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 5/7)

(1970)

This Report is based on Doc. VII/53 (U.S.A.), 1966-1969.

1. System for precise time

1.1 Recent advances in the techniques for establishing and maintaining precise time and frequency synchronization between ground and airborne stations [1] are being investigated to determine

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* This Report was adopted unanimously.

to what extent they can meet future stringent requirements for aviation purposes [2]. The concept of a time ordered system (TOS) depends on such advanced time/frequency (*T/F*) techniques suitably directed towards future systems' needs. Such TOS concepts require that air-ground equipment should be capable of establishing and maintaining precise synchronization to a world-wide time reference. This precise world-wide time reference is used as the common reference for the exchange of system data between aircraft and between aircraft and ground stations. Appropriate data processing at either ground or airborne stations then provides for many integrated system functions from a single basic system design. Integrated system functions required for aviation needs include airborne collision avoidance systems (CAS), position determination, navigation and communication. The future operational success or failure of such time ordered, integrated systems depends in major part on establishing and maintaining a master or world-wide scale coordinated to the order of 0·1 to 1·0 μs.

1.2 The selection of precise *T/F* techniques [3] as the basis for the design of air-to-air CAS equipment for airline use constitutes a significant step forward in attaining acceptance by the aviation user of a precise time ordered system for eventual development on a world-wide basis. The design concept recognizes and allows for future, and as yet unresolved, operational requirements in the congested terminal areas [1]. One preliminary design goal [1] is for time synchronization of ground stations to a single world-wide standard time to within 0·5 μs (3σ).

1.3 Analyses are now being conducted by the United States Federal Aviation Administration (FAA) to establish what improvements in air traffic management might be achieved by the application of broad, integrated systems of *T/F* technology. The results indicate that appropriate developments of time ordered systems can be expected to meet aviation performance requirements for several decades ahead. Studies to date show that the available methods of achieving system master time, using a world-wide timing reference are capable of providing adequate performance for distance measuring equipment, navigation, data acquisition, landing aid and station keeping in addition to CAS. This preliminary concept study indicates timing requirements to be of the same order of accuracy as for the CAS function cited above, i.e. about 0·1 to 0·5 μs.

2. System standards

2.1 Consideration has been given to the relationship between CAS performance [4], internal system synchronization [5], signals-in-space [6], *T/F* technology [7], and master timing requirements as they relate to future development of an acceptable world-wide timing reference [8]. The problem of distributing time around the world and maintaining common world-wide time in secondary ground reference stations has been analyzed in the development of concepts for future designs of multi-function integrated time ordered systems for aviation. Such considerations have raised several important questions that must be resolved before agreement can be reached on a world-wide timing specification.

2.2 These questions relate, in part, to the selection of a common time scale, standardization of the synchronizing signals, determination of radio frequency spectrum requirements, compatibility of signals serving single-function (CAS) versus multiple-function aviation systems, and the development of *T/F* system requirements for other world interests. Consideration has been given to the application to CAS of a uniform time scale, such as A.1 [8]. Future designs for multi-function time ordered aviation systems and the analysis of other world-wide interests, in addition to aviation, may suggest the use of alternative time scales in the initial development of a world-wide time reference. The common basis of time ordered systems is the need for precise synchronization between all participating stations in the system. Means of standardizing the basic synchronization portion of the signals-in-space from secondary ground station emissions should be considered on a world-wide basis to permit the maximum number of users to benefit from the dissemination of the primary world-wide time reference.

3. System studies

3.1 The system application of precise time and frequency technology is in its infancy and the full performance and economic potential of cooperative integrated systems based on this advanced *T/F* technology has yet to be developed and demonstrated before acceptance of such an approach can be justified by Administrations. Such development and demonstration activity has been initiated by the United States through a broad programme ranging from concept analyses and system designs to flight tests of critical elements, in order to meet the needs of aviation. It is expected that this activity will lead to the formulation of the requirements for gradually extending a precise timing system throughout the world. The necessity for compatible, cooperative *T/F* operation in such systems emphasizes the need for appropriate studies aimed at world-wide timing requirements and the solution of some of the problems cited above.

Such studies should be kept extremely broad in nature and not be constrained to the specialized applications of specific Administrations, or users. They might provide a most valuable service by the analysis and definition of the relative benefits of various methods of disseminating and maintaining a world-wide time reference with a synchronization capability of 0·1 μs. An additional advantage to be gained could be that the timing accuracy required for aviation may also meet the needs of other world-wide interests.

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REPORT 439*

THE USE OF COORDINATE CLOCKS AND LOCAL STANDARD (METRIC) CLOCKS IN A TERRESTRIAL COORDINATE TIME SYSTEM

(Question 6/7, Study Programme 6A/7)

(1970)

Introduction

Coordinate time and metric time (proper time) are both primary concepts in timekeeping and time interval measurement. If several coordinate time systems exist, the relation between them should be known. These relations are called "equations of transformation". The use of atomic standards of time makes possible their systematic employment in the measurement of the properties of coordinate time (and space) systems. Some measurements are now being reported, and are becoming part of a widespread coordinated programme.

A clock, running independently of other clocks, constructed to generate seconds and evaluated for its accuracy, is a metric instrument usable for physical measurement of time intervals and frequencies. Its use as a standard calibration device should be under conditions as nearly ideal as possible, which require a minimum of theoretical assumptions.

A set of clocks distributed over a spatial region, synchronized by physical means, such as radio time signals, constitutes part of a coordinate time system. The system is completed by incorporating a time scale defined at an appropriately chosen spatial origin, means for measuring its operation and procedures for maintaining the system control. To ensure permanence, observations relating to the system scale to astronomical scales are desirable.

The time scale at the origin

Many coordinate time scales can be defined. The Consultative Committee for the Definition of the Second of the International Committee of Weights and Measures (C.I.P.M.) has established [1, 2] that two coordinate time scales were particularly important: one for application on the Earth's surface, called the terrestrial time scale, and the other for describing the movement of celestial bodies, called the celestial time scale. Definitions of the corresponding units of time were proposed as scale measures in [1, 2]. Only the concept of terrestrial time is dealt with here.

The introduction of an official international coordinate time scale corresponding to the concept of terrestrial time is desired. The formal definition of an appropriate scale measure related to the SI second undoubtedly falls within the competence of the C.I.P.M.

With regard to the practical problem of establishing an international coordinate time scale on the basis of a large number of clocks or groups of clocks, it would appear desirable and urgent to develop and implement, internationally, averaging procedures including the determination of the statistical weights to be assigned to clocks and groups of clocks. The different stabilities and intrinsic accuracies of clocks used to establish the time scale as well as differing uncertainties in the comparison methods used should be considered.

Since 1 January 1969, the B.I.H. has computed a time scale which is uniform to an approximation of about 1×10^{-13} [3]. This time scale is made available to 0·2 μs by publishing corrections to individual clock times. Effective synchronization of clocks with the B.I.H. time scale may be easily maintained within the limits of 1 μs. Since no reference level has been

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* This Report was adopted unanimously.

fixed and consequently no relativistic correction is made at present, the time scale can be designated as well as a proper time scale.

Regular time comparisons between a number of local standards of time, running independently, and at large distances from each other, are obtained to nearly 0·1 μs through the intermediary of LORAN-C signals (covering the North Atlantic and the Mediterranean) or from television pulses [5, 6]. These signals are corrected for propagation delay times and instrumental retardations using the transport of clocks. A weighting procedure, at present rather arbitrary, is used to form the international scale at the origin.

The use of this procedure allows a record to be kept of the fractional frequency difference, $F(i)$, of the ith standard clock from the average time scale of the B.I.H.

Coordinate times

A coordinate clock reading at the i^{th} location may be derived from the local standard clock reading by considering the fractional frequency deviation $F(i)$ and a relativistic frequency shift $G(i)$. $G(i)$ is given by:

$$G(i) = g \frac{H(i)}{c^2}$$

where $H(i)$ is the height of the i^{th} location above the system origin, g is the acceleration of gravity, assumed uniform, and c is the velocity of light. If:

$$Q = \frac{1 - G(i)}{1 + F(i)}$$

and $AT(i)$ is the local standard clock reading, the reading of the coordinate clock is:

$$ATC(i) = Q \times AT(i),$$

the initial readings of these clocks being assumed equal to zero and corresponding to the same instant. The use of the factor Q maintains the synchronization of $ATC(i)$ with the coordinate time of the system.

An additional frequency offsetting procedure for changing the rates of both the coordinate clocks and the local standards of time may be applied in order to maintain approximate synchronization of the coordinate clocks with universal time. This additional procedure is also described in [4] for a national coordinate time system now being studied in the United States of America.

System operation

Carrier and time-signal frequencies emitted from the i^{th} location will be equal to the system frequencies at the system origin.

At the system origin, the difference Δ(UT) between universal time and the system coordinate time may be determined. The values of $ATC(i)–AT(i)$ should be made available.

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REPORT 517*

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

Detailed instructions by Study Group 7 for the implementation of Recommendation 460 concerning the improved Coordinated Universal Time (UTC) System, valid from 1 January 1972

(Question 1/7, Resolution 53)

(1971)

1. The XIIth Plenary Assembly of the C.C.I.R. adopted unanimously Recommendation 460. According to § 4 of this Recommendation, Study Group 7 was entrusted with the task of formulating the detailed instructions for its implementation on 1 January 1972.

Study Group 7 met from 17-23 February 1971 and adopted the following text for this purpose:

2.

2.1 A special adjustment to the standard-frequency and time-signal emissions should be made at the end of 1971 so that the reading of the UTC scale will be 1 January 1972, $0^h\ 0^m\ 0^s$ at the instant when the reading of Atomic Time (AT) indicated by the Bureau international de l'Heure (B.I.H.) will be 1 January 1972, $0^h\ 0^m\ 10^s$. The necessary adjustments to emissions which are in accordance with Recommendation 374-2 will be specified and announced in advance by the B.I.H.

2.2 The departure of UTC from UT1 should not normally exceed 0·7 s**.

2.3 Inserted seconds should be called positive leap seconds and omitted seconds should be called negative leap seconds.

2.4 A positive or negative leap second, when required, should be the last second of a UTC month, preferably 31 December and/or 30 June. A positive leap second begins at $23^h\ 59^m\ 60^s$ and ends at $0^h\ 0^m\ 0^s$ of the first day of the following month. In the case of a negative leap second, $23^h\ 59^m\ 58^s$ will be followed one second later by $0^h\ 0^m\ 0^s$ of the first day of the following month. (See Annex I).

2.5 The B.I.H. should decide upon and announce the occurence of a leap second; such an announcement is to be made at least eight weeks in advance.

2.6 The time signals of standard-frequency and time-signal emissions should be kept as close to UTC as possible, with a maximum deviation of one millisecond.

3.

3.1 The approximate value of the difference UT1 minus UTC, as disseminated with the time signals should be denoted DUT1,

where DUT1 $\approx$ UT1–UTC.

DUT1 may be regarded as a correction to be added to UTC to obtain an approximation of UT1.

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* This Report was adopted unanimously.

** Universal Time

In applications in which errors of a few hundredths of a second cannot be tolerated, it is necessary to specify the form of Universal Time (UT), referred to in Recommendation 460, which should be used.

UT1 is a form of UT in which corrections have been applied for the effects of small movements of the Earth relative to the axis of rotation.

UT2 is UT1 corrected for the effets of a small seasonal change in the rate of rotation of the Earth.

UT1 correspond directly with the angular position of the Earth around its axis of rotation, and is used in this document. GMT may be regarded as the general equivalent of UT1.

3.2 The values of DUT1 should be given in integral multiples of 0·1 s. The B.I.H. is requested to determine and to circulate one month in advance the value of DUT1. Administrations and organizations should use the B.I.H. value of DUT1 for standard-frequency and time-signal emissions whenever possible, and are requested to circulate the information as widely as possible in periodicals, bulletins, etc.

3.3 Where DUT1 is desseminated by code, the code should be in accordance with the following principles:

— the magnitude of DUT1 is specified by the number of emphasized seconds markers and the sign of DUT1 is specified by the position of the emphasized seconds markers with respect to the minute marker. The absence of emphasized markers indicates $DUT1 = 0$;

— the coded information should be emitted after each identified minute.

Full details of the code are given in Annex II.

3.4 Alternatively DUT1 may be given by voice announcement or in morse code.

3.5 In addition, UT1-UTC may be given to the same or higher precision by other means, for example, in morse or voice announcements, by messages associated with maritime bulletins, weather forecasts, etc.; announcements of forthcoming leap seconds may also be made by these methods.

3.6 The B.I.H. is requested to continue to publish in arrears definitive values of the differences UT1-UTC, UT2-UTC and AT (B.I.H.)-UTC.

ANNEX I

DATING OF EVENTS IN THE VICINITY OF A LEAP SECOND

(Taken from § 2.4 of the Report)

A positive or negative leap second, when required, should be the last second of a UTC month, preferably 31 December and/or 30 June. A positive leap second begins at $23^{h}\ 59^{m}\ 60^{s}$ and ends at $0^{h}\ 0^{m}\ 0^{s}$ of the first day of the following month. In the case of a negative leap second, $23^{h}\ 59^{m}\ 58^{s}$ will be followed one second later by $0^{h}\ 0^{m}\ 0^{s}$ of the first day of the following month.

Taking account of what has been said in the preceding paragraph, the dating of events in the vicinity of a leap second shall be effected in the manner indicated in the following figures:

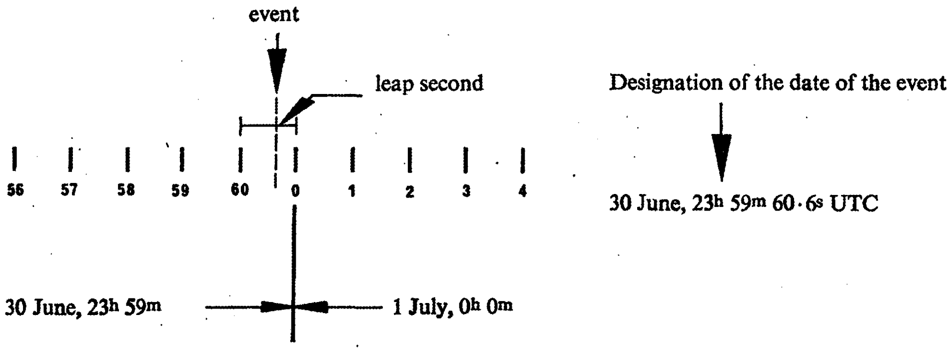

FIGURE 1

Positive leap second

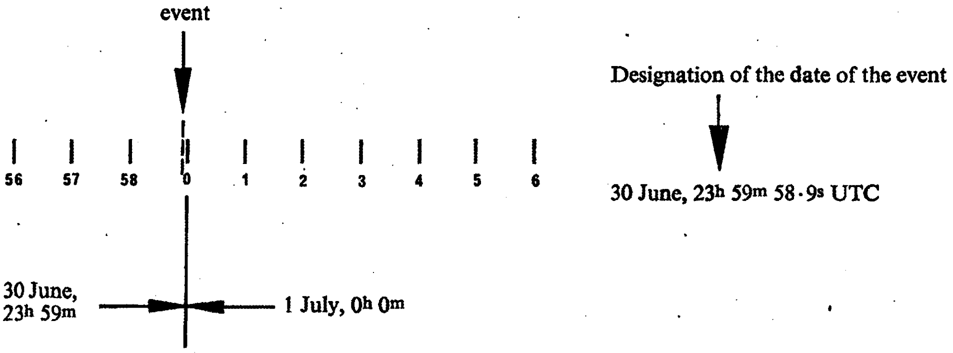

FIGURE 2

Negative leap second

ANNEX II

CODE FOR THE TRANSMISSION OF DUT1

A positive value of DUT1 will be indicated by emphasizing a number (n) of consecutive seconds markers following the minute marker from seconds markers one to seconds marker (n) inclusive; (n) being an integer from 1 to 7 inclusive.

$$DUT1 = (n \times 0{\cdot}1)s$$

A negative value of DUT1 will be indicated by emphasizing a number (m) of consecutive seconds markers following the minute marker from seconds marker nine to seconds marker (8 + m) inclusive; (m) being an integer from 1 to 7 inclusive.

$$DUT1 = -(m \times 0{\cdot}1)s$$

A zero value of DUT1 will be indicated by the absence of emphasized seconds markers.

The appropriate seconds markers may be emphasized, for example, by lengthening, doubling, splitting, or tone modulation of the normal seconds markers.

Examples:

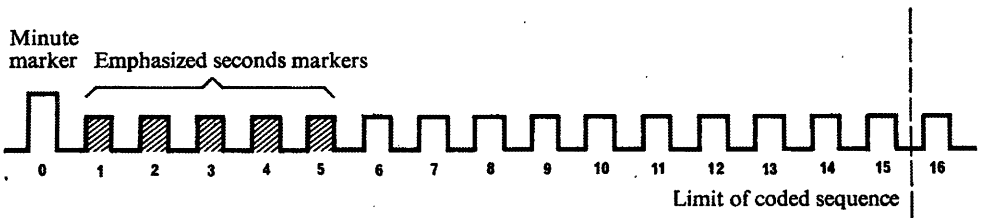

FIGURE 3
DUT1 = +0·5 s

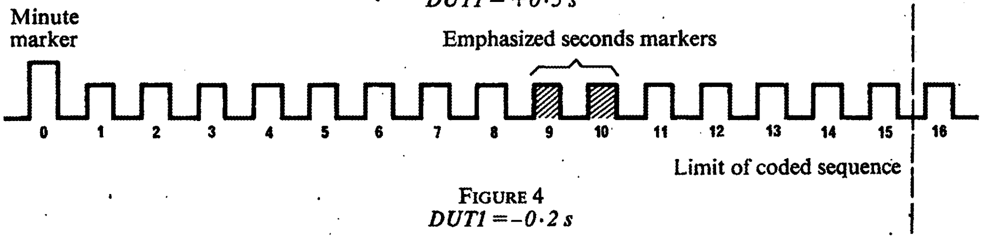

FIGURE 4
DUT1 = −0·2 s

REPORT 518*

STANDARD FREQUENCY AND TIME-SIGNAL EMISSIONS FROM SATELLITES**

(Question 2/7, Study Programme 2A-1/7)

(1971)

The object of this Report is to review the present situation with regard to the use of satellites for the dissemination of standard frequencies and time signals. General conclusions regarding the use of satellites by the Standard Frequency and Time Signal Service are given below [1, 2].

The signals in band 7 no longer serve many of the purposes for which they were originally designed. Propagation characteristics in band 7 are responsible for serious difficulties and, in general, 24-hour service cannot be obtained from a single station at a single frequency. Thus, the user must monitor two or more stations at several frequencies to obtain continuous service and in some areas it is not possible to obtain any service at all. The resulting multiplicity of stations gives rise to problems of interference which can only be alleviated by inconvenient time-sharing arrangements.

A solution of these difficulties which has potentially wide-spread applications is to disseminate standard-frequency and time-signals via satellites. Two general cases may be distinguished in this Report:

A. One-way broadcast operation

B. Two-way operation

In this context, one-way operation means that the user employs only receiving equipment, a common transmission, originated or relayed by a satellite, reaching a large number of users. Two-way operation is that in which the user employs both transmitting and receiving equipment.

A. One-way operation has the following characteristics:

- wide spread service areas;
- timing accuracy of 100 microseconds, using satellite position predictions issued as infrequently as one month in advance. More frequent predictions allow better accuracies to be achieved;
- the signal quality and reliability are excellent;
- the method for time recovery and for operating the equipment are both simple;
- equipment costs and complexity can be moderate.

B. Two-way operation has the following characteristics:

- timing accuracies of the order of 100 nanoseconds have been achieved;
- it is easily confined to limited areas on the Earth, if necessary, when higher frequencies are being used;
- it may often be the only practicable way to effect comparisons or to receive time and frequency in certain remote areas with an uncertainty less than 1μs.

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* This Report was adopted unanimously.

** Note by the Secretariat
This Report has been brought to the attention of the special joint meeting of C.C.I.R. study groups to prepare the technical basis for the World Administrative Radio Conference for Space Telecommunications, (Geneva, 1971).

Both these modes of operation would best be served by a geostationary satellite, although a non-stationary satellite might be useful in special cases.

A time service via satellite may *satisfy many of the needs of various classes of users*, most of whom demand *continuous 24-hour service*. Some of the anticipated uses include:

- improved service for scientific purposes such as geophysical and geodetic work;
- service for precise surveying on land or at sea, particularly in remote areas;
- requirements by mobile services on a 24-hour basis more exacting than those of ordinary navigation;
- accurate time comparisons and coordination of time scales such as required by national laboratories and others.

The possibility of fulfilling these tasks by the Standard Frequency and Time Service via satellites requires that the transmission be made in frequency ranges relatively insensitive to propagation anomalies and man-made interference. *Frequency allocations, preferably exclusive, are therefore sought in band 9 and in band 10.* The lower part of band 9, with 100 kHz bandwidth would satisfy users needing 10 to 100 μs accuracy with simple equipment readily available to-day. The use of frequencies in band 10 with a bandwidth of 1–4 MHz would permit greater accuracy and reduces the effect of propagation difficulties. Their use would also facilitate limited area coverage and the satellite antennae would be reduced in size and mass.

Much work remains to be done towards specifying systems which would meet the general service requirements of all users. Indeed, various types of systems or transmission schemes can be conceived which could provide the required performance. *It can however be stated at this stage that a system to provide accurate time signals via satellite would represent a significant improvement* in world wide dissemination of precise time [3].

Administrations should therefore give careful consideration to system configurations which would provide the services discussed above, so that allocations of the spectrum may be made both in the lower portion of band 9 and in the lower part of band 10, preferably on an exclusive basis.

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QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS

(STUDY GROUP 7)

QUESTION 1/7

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-1/7

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965 – 1970)

CONSIDERING

(a) that Question 1/7 and Recommendation 374-2 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 simultaneously on the same carrier frequency;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the possibilities of reducing mutual interference between emissions in standard-frequency and time-signal 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 emitted frequencies 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;

1.5 avoiding unmodulated carrier emissions, not strictly necessary for the operation of the service;

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-1/7

SINGLE-SIDEBAND OPERATION FOR THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICES

The C.C.I.R., (1965 - 1970)

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, to reduce 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-1/7

TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965 - 1970)

CONSIDERING

the desirability for providing both universal time (UT) and atomic time scale (AT) in the same emission;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the possibility of developing improved methods by active pursuit of studies and experiment to provide both universal time (UT) and atomic time scale (AT) in the same emission.

STUDY PROGRAMME 1D/7

STATISTICAL WEIGHT OF CLOCKS USED TO ESTABLISH A TIME SCALE — AVERAGING PROBLEMS

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

CONSIDERING

(a) that atomic time scales are often obtained by establishing the individual time scale averages of a large number of clocks or groups of clocks remotely located from each other;

(b) that for many applications it is important that a time scale should be as uniform as possible;

(c) that in addition the sub-division of the time scales should be made in agreement with the accepted value of the second;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the averaging procedures, including the determination of the statistical weight assigned to clocks or groups of clocks used in establishing the time scale, to be recommended.

It should be recognized that the intrinsic accuracy and stability of such clocks may differ, that commercial-type clocks as well as laboratory models must be considered and that the clock readings are ascertained with varying degrees of accuracy by those dealing with averaging problems;

2. the procedures to be recommended in cases where the number and/or accuracy of the clocks used to establish a time scale changes.

QUESTION 2/7

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;

(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-1/7

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS FROM SATELLITES

The C.C.I.R., (1963 - 1970)

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 4 describes radiocommunication systems making use of satellites which can be expected to give extensive coverage and satisfactory stability of signals over the Earth's surface;

UNANIMOUSLY DECIDES that the following studies should be carried out:

the technical factors and quantitative measures to be considered 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 satellites.

QUESTION 3/7

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;

(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-1/7

FREQUENCY-SPECTRUM CONSERVATION FOR HIGH PRECISION TIME SIGNALS

The C.C.I.R., (1959 – 1970)

CONSIDERING

(a) that higher precision in the radio distribution of time signals necessitates, with present techniques, the use of an increased bandwidth;

(b) that newly developed techniques may, nevertheless, effect a considerable economy for a given precision;

(c) the effects of noise of all types on system performance;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the relationship between bandwidth required, and precision obtainable at present for various signal-to-noise ratios 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/7

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;

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-1/7

INTERNATIONAL COMPARISON OF STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1965 - 1970)

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 Ottawa, 1969, at its XVIth 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 satellites, etc.).

STUDY PROGRAMME 3D/7

METHODS FOR RELIABLE VERY LOW FREQUENCY PHASE COMPARISONS

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

CONSIDERING

(a) that it is often necessary to produce a mean value based on the time scales of distant clocks or groups of clocks and that, for this purpose, extensive use is made of very low frequency (VLF) phase comparisons;

(b) that, in comparisons of VLF phase, the risk exists at present that the phase continuity as received may be lost from time to time, and that each loss of the phase continuity may cause error which cannot be considered negligible;

(c) that it is extremely desirable that organizations contributing to the formation of international time scales by means of VLF phase comparisons should use only calibrated measuring devices;

(d) that the use of calibrated measuring devices is an essential pre-requisite for a thorough study of the problems of VLF propagation;

(e) that it is advisable to measure VLF phase values at the most favourable time of the day from the standpoint of the reliability of the received signal phase;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. how to promote the development and application of apparatus which allows for calibration for VLF phase comparisons;
2. investigation of the propagation behaviour at VLF in order to determine the most favourable reception conditions for daily phase comparisons.

QUESTION 4-1/7

DISSEMINATION OF STANDARD FREQUENCIES AND TIME SIGNALS

The C.C.I.R., (1965 - 1970)

CONSIDERING

(a) the need for increased accuracy of standard frequency and time signals;

(b) that the present standard-frequency and time-signal emissions, as received, are degraded in accuracy 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 improving the accuracy of disseminated standard frequencies and time signals?

STUDY PROGRAMME 4-1A/7

DISSEMINATION OF STANDARD FREQUENCIES BY CARRIER-FREQUENCY STABILIZATION OF BROADCASTING EMISSIONS

The C.C.I.R., (1966 - 1970)

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.

QUESTION 5/7

HIGH PRECISION STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

The C.C.I.R., (1968)

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.);

UNANIMOUSLY 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)?

QUESTION 6/7

SYSTEMS OF COORDINATE TIME

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

CONSIDERING

(a) that the second has been defined by the General Conference of Weights and Measures in October, 1967, in terms of a caesium transition frequency for the purpose of the International System (SI) of units;

(b) that other units of time may continue to be used outside the SI;

(c) that certain problems concerning the distribution of time and frequency signals are raised by the application of the new definition of the second;

(d) that the technical basis for setting up a coordinate time system points to the need for a spatial origin of the system;

(e) that the use of a scale of atomic time in many localities is an established fact;

(f) that a disseminated time cannot be made to agree everywhere with local scales of atomic time;

(g) that relativistic effects will become increasingly important, particularly in view of space applications;

UNANIMOUSLY DECIDES that the following question should be studied:

1. how can international systems of coordinate time signals best be defined and implemented;
2. what systems will be most economical and technically adequate for the given purposes?

Note. — Coordinate time should not be confused with UTC (Coordinated Universal Time).

STUDY PROGRAMME 6A/7

SYSTEMS OF COORDINATE TIME

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

CONSIDERING

(a) that the technical basis for setting up a coordinate time system points to the need for a spatial origin of the system;

(b) that the use of a scale of atomic time in many localities is an established fact;

(c) that a disseminated time cannot be made to agree everywhere with local scales of atomic time;

(d) that relativistic effects will become increasingly important, particularly in view of space applications;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the procedures that may conveniently be adopted to specify various systems of coordinate time;
2. the determination with great accuracy and convenience, and with a minimum of non-operational assumptions, of the difference between a coordinate time and local atomic time, throughout extensive space regions.

RESOLUTION 14-2

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

The C.C.I.R., (1963 – 1966 – 1970)

CONSIDERING

the provisions of Article 44, Section IV, of the Radio Regulations,

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; 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, in addition, 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) to the Chairman, Study Group 7, and to the Directors, C.C.I.R., and B.I.H. for official publication within the shortest possible time;
3. that Study Group 7 should cooperate with the I.A.U. (International Astronomical Union), the U.R.S.I. (International Scientific Radio Union), the I.U.G.G. (International Union of Geodesy and Geophysics), the I.U.P.A.P. (International Union of Pure and Applied Physics) and the B.I.H. (International Time Bureau).

RESOLUTION 52

FORMS OF EXPRESSION FOR USE IN THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICE

(Question 1/7)

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

UNANIMOUSLY DECIDES

1. that an Interim Working Party 7/2 be set up to study:

1.1 the forms of expression of all kinds (such as terms, symbols and their definitions) and the condition of their use in the standard-frequency and time-signal service;

1.2 to report the conclusions of its work as soon as possible to Study Group 7;

2. the Chairman of this Interim Working Party shall be: Prof. C. Egidi, Istituto Elettrotechnico Nazionale Galileo Ferraris, Corso Massimo d'Azeglio 42, Torino, Italy;

3. the work shall be carried out as far as possible by correspondence;

4. the Interim Study Group on Vocabulary (CIV) shall be informed of the progress of this Working Party.

ANNEX

The Administrations of Argentina, Canada, France, Italy, Japan, Federal Republic of Germany, United States of America, U.S.S.R., as well as the B.I.H. and I.A.U., have already indicated their intention and desire to participate in the work of Interim Working Party 7/2.

RESOLUTION 53

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

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

CONSIDERING

the provisions of Recommendation 460;

UNANIMOUSLY DECIDES

1. that the International Working Party VII/1, formed at the interim meeting of Study Group VII in Boulder, Colorado, 1968 according to Doc. VII/70, 1966-1969, should continue its work with the following terms of reference:

1.1 to study and to propose to the next interim meeting of Study Group 7 the detailed procedures to be recommended in consequence of the adoption of Recommendation 460;

2. that participants in the work of C.C.I.R. Study Group 7 be requested to undertake experimental investigations of methods of informing users of universal time (UT) of the differences between UT and the radio time signals as emitted, and to report their results and suggestions before 1 January 1971 to the Chairman of Interim Working Party 7/1;

3. that this document be transmitted by the Director, C.C.I.R., to all Administrations Members of the I.T.U., to the scientific Unions: I.A.U., I.U.G.G., U.R.S.I., I.U.P.A.P. and other organizations such as B.I.H., C.I.P.M., I.C.A.O. and I.M.C.O., inviting them to send their comments and proposals before 1 January 1971, to the Chairman of Interim Working Party 7/1.

OPINION 26-1

STUDIES AND EXPERIMENTS CONCERNED WITH TIME-SIGNAL EMISSIONS

(Question 1/7)

The C.C.I.R., (1966 – 1970)

CONSIDERING

(a) that frequency and time may be provided in the same emission;

(b) the present necessity for providing both universal time (UT) and atomic time scale (AT) in the same emission;

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.), the International Committee of Weights and Measures (C.I.P.M.) 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 7 in pursuing studies and experiments relative to the following problems:

1.1 how to provide both universal time (UT) and atomic time scale (AT) 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 7, should communicate with the Chairmen of the appropriate Commissions of the U.R.S.I., the I.A.U., the I.U.G.G., the C.I.P.M. 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.

OPINION 27

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/7)

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.

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.

OPINION 36

TIME SCALES

(Study Programme 1C-1/7)

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

CONSIDERING

that the introduction of the time scale based on the atomic standards will cover fully the necessities of pure and applied physics, while the universal time (UT) scale covers the necessities of astronomy, geodesy and astronomical navigation, being related to the angular position of the Earth;

IS UNANIMOUSLY OF THE OPINION

that the I.A.U. and the I.U.G.G. should be asked to consider whether the UT scale could be considered henceforth as an angular measure and should be differentiated accordingly.

Note. — The Director of the C.C.I.R. is asked to transmit this Opinion to the I.A.U. and I.U.G.G.

OPINION 37

DEFINITION OF AN INTERNATIONAL COORDINATE TIME SCALE

(Question 6/7, Study Programme 6A/7)

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

CONSIDERING

(a) that the improvement in the near future of the accuracy of time and frequency standards will make necessary consideration of relativistic effects;

(b) that the definition of a coordinate time for official applications comes within the competence of the C.I.P.M. which has already considered in its work some relativistic and other effects;

(c) that the best procedure for the introduction of a coordinate time in countries signatory to the Convention on the Metre would appear to ask for a recommendation of the C.G.P.M.;

IS UNANIMOUSLY OF THE OPINION

that the C.I.P.M. and the C.G.P.M. be asked for the definition of an official coordinate time system.

Note. — The Director of the C.C.I.R. is asked to transmit this Opinion to the C.I.P.M. and also to U.R.S.I., I.A.U., I.U.G.G., I.U.P.A.P. and the B.I.H. for information.

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VOCABULARY

INTERIM STUDY GROUP ON VOCABULARY (CIV)

Terms of reference:

To study, in collaboration with the other Study Groups and, if necessary, with the C.C.I.T.T., the radio aspect of the following: vocabulary of terms and list of definitions, lists of letter and graphical symbols and other means of expression, systematic classification, measurement units, etc.

Chairman:	R. Villeneuve (France)
Vice-Chairman ad interim:	B.L. Durán (Spain)

INTRODUCTION BY THE CHAIRMAN, INTERIM STUDY GROUP ON VOCABULARY (CIV)

1. Preamble

The subjects which the CIV is called upon to study under its terms of reference, which are given below, distinguish this Study Group radically from all the others, which differ among themselves only in the specialized branch of radio technique assigned to them.

The common feature of all these CIV subjects is that the aim of studying them, whether they concern terminology or other means of expression, is always to codify usage. This essential feature of the subjects is reflected in the work done on them, which invariably demands a very high degree of coordination and cooperation at all levels, in an attempt to achieve a *homogeneous codification* for each sector and to avoid all discrepancies with the work of others.

In this work of codification, the conventions which suit the purposes of the C.C.I.R. Study Groups should not only form a consistent system, but should also agree as closely as possible with the conventions in use elsewhere, whether within the I.T.U. or outside it.

With a view to achieving homogeneity in codification, first of all within the I.T.U., and in accordance with the proposals of International Working Party PLEN/1, which recommended in connection with the reorganization of the C.C.I.R. Study Groups that C.C.I.T.T. Study Group VII and C.C.I.R. Study Group XIV be merged in a single Joint Study Group on Vocabulary (CMV), the Plenary Assembly of the C.C.I.R. proposed that such a Study Group be set up under the chairmanship of Mr. R. Villeneuve (France) and that the Vice-Chairman be appointed by the next Plenary Assembly of the C.C.I.T.T. The terms of reference of this Joint Study Group would be:

— To study, in collaboration with the Study Groups of C.C.I.R. and C.C.I.T.T., technical terminology and related subjects (graphical and letter symbols and other means of expression, systematic classification, units of measurement, etc.) in order to meet the needs of these Study Groups and to make the best possible use of the joint cooperation groups established between the C.C.I.'s and the corresponding technical committees of the International Electrotechnical Commission (e.g. Technical Committee No. 1 for terminology and Technical Committee No. 3 for graphical symbols).

The Director, C.C.I.R., therefore asked the Director of the C.C.I.T.T. to bring this proposal to the notice of the next Plenary Assembly of the C.C.I.T.T.

Pending the decision of the C.C.I.T.T. on this proposal, the Plenary Assembly of the C.C.I.R. decided to set up an Interim Study Group on Vocabulary (with the acronym CIV in all three languages), retaining the terms of reference of C.C.I.R. Study Group XIV. The

Note by the Secretariat:

The Vth Plenary Assembly of the C.C.I.T.T., Geneva, December, 1972, adopted the proposal of the XIIth Plenary Assembly of the C.C.I.R., New Delhi, 1970, concerning the establishment, under Chapter 19 of the General Regulations annexed to the International Telecommunication Convention, Montreux, 1965, of a Joint Study Group of the two C.C.I.s for Vocabulary and related questions.

This Plenary Assembly of the C.C.I.T.T. also adopted the terms of reference drawn up by the XIIth Plenary Assembly of the C.C.I.R. for this new Joint Study Group.

The new Joint Study Group thus created, designated CMV, is regarded as having been established as of 1 January 1973.

The Vth Plenary Assembly of the C.C.I.T.T. also agreed that this Joint Study Group, which supersedes C.C.I.T.T. Study Group VII as it existed until the Vth Plenary Assembly, and C.C.I.R. Study Group CIV, should be administered by the C.C.I.R.

CMV

Joint C.C.I.R./C.C.I.T.T. Study Group for Vocabulary

Terms of reference:

To study, in collaboration with the Study Groups of the C.C.I.R. and C.C.I.T.T., technical terminology and related subjects (graphical and letter symbols and other means of expression, systematic classification, units of measurements, etc.) to meet the needs of these Study Groups, making the best possible use of the joint cooperation groups established between the C.C.I.'s and the corresponding technical committees of the International Electrotechnical Commission (e.g. Technical Committee No. 1 for vocabulary and Technical Committee No. 3 for graphical symbols).

Chairman:	R. Villeneuve (France)
Vice-Chairmen:	M. Ducommun (Switzerland)
	B.A. Durán (Spain)

Plenary Assembly also appointed Mr. B.A. Durán (Spain) Vice-Chairman of the CIV until such time as it is replaced by the proposed Joint Study Group.

2. Graphical symbols

The work done by the Joint Working Party, in which representatives of both C.C.I.'s and of the IEC cooperate, and C.C.I.R. participation in which was approved by Resolution 23, produced the following three texts:

- Recommendation 461, which advocates the use of the set of symbols now published in final form by the IEC;
- Report 440, published separately, containing the symbols which the above Recommendation advocates for use;
- Report 335-1, which contains symbols adopted by the IEC but not yet published in final form and which was brought up to date to take into account the work of the Joint Working Party during the period 1966–1969.

The Joint Working Party has now completed the bulk of the work relating to graphical symbols which may be of interest to the C.C.I.R.; it now has only a limited number of chapters to deal with and possibly to add supplements to existing chapters.

3. Terminology

The most important part of the CIV's work is concerned with the preparation of the vocabulary.

3.1 *Establishment of the Joint IEC/CCIR-CCITT Coordination Group to supervise the joint preparation of the telecommunication vocabulary*

The successful conclusion of earlier efforts to organize really close cooperation between the C.C.I.'s and the IEC is the major development to be reported.

A Joint Coordination Group, contemplated since 1967, was finally set up in 1969. It was able to hold its first meeting in conjunction with the final Study Group meetings in Geneva in October, 1969.

To enable the C.C.I.R. to adjust to this new organization of work, it adopted Resolution 21-2, concerning Interim Working Party CIV/1 which deals with these questions, which introduced some amendments into Resolution 21-1 (1966):

- with regard to the organization of terminology work in the C.C.I.R., the Resolution stresses the increased importance of the help expected from the specialized collaborators belonging to various Study Groups. It confirms the value, which had become apparent at the Oslo Plenary Assembly, 1966, of taking into account the work of Administrations participating actively in terminology work through national collaborators, some of whom had enabled the Group to benefit by their long experience of such vocabulary problems as: the usefulness of classifying new proposals for definitions in several categories and according to certain criteria; the need to draw up, without too much loss of time due to linguistic problems, a multilingual vocabulary with a sound concordance of terms between the various languages, taking as a basis, not a list of "terms" proper to each language, but a list of "concepts" representing what users of the vocabulary have in common, despite language differences;
- with regard to relations between Interim Working Party CIV/1 and the Joint IEC/CCIR-CCITT Coordination Group created to supervise the preparation of the vocabulary, the Resolution covers the following main points:

— plan for dividing the work into chapters and subdivisions;

— an unequivocal system of numbering;

— relations between the activities of Interim Working Party CIV/1 and work done under the auspices of the Joint Coordination Group.

With regard to the last-named point, the members of Study Group XIV urged that it should be kept informed of the progress of work. Resolution 21-2 was supplemented by Report 441, giving the necessary information on the operation of IEC Technical Committee No. 1 (Terminology), on the cooperation on an equal footing established between the IEC and the C.C.I.'s and on the role of the CIV.

Very shortly after this clarification by C.C.I.R. Study Group XIV, the Joint Coordination Group held its first meeting on 14 and 15 October 1969. The Group consisted of twelve members (six from the C.C.I.'s and six from the IEC), under the chairmanship of Mr. R. Villeneuve; Mr. Nasse of the IEC acted as Secretary. The purpose of this first meeting was to lay the foundations for effective cooperation between the C.C.I.'s and the IEC and to begin by dividing the whole telecommunication vocabulary into a certain number of chapters, to allow for the establishment of joint groups of experts each responsible for one chapter.

This initial work of division of the vocabulary into chapters by the Joint Coordination Group is proceeding satisfactorily. A recent meeting of IEC Technical Committee No. 1 (Washington, May 1970) provided an opportunity for some of the dozen Group members to meet and for the work to reach a stage that will make it possible shortly to constitute quite a large number of joint groups of experts.

3.2 *Special points of terminology*

The Annex to this Introduction, p. 276, gives a recapitulatory list of C.C.I.R. texts dealing with terminology.

3.3 *Interim working parties dealing with vocabulary other than Interim Working Party CIV/1*

International Working Party XIV/2, set up at the XIth Plenary Assembly in Oslo (under Resolution 21-1, referred to in Annex I, § 2.2) and presided over by Dr. Kaiser, is concerned with *reliability* terminology. The New Delhi Plenary Assembly, 1970, unanimously recommended that this Working Party be maintained; it is now called Interim Working Party CIV/2.

A new Resolution 54 set up Interim Working Party CIV/3, under the chairmanship of Mr. N. Chistiakov, to study terms and definitions relating to sound and video *recording*.

4. Other means of expression

4.1 *Units of measurement*

Recommendation 430, advocating the adoption of the international MKSA system by members of the C.C.I.R., was maintained.

4.2 *Letter symbols and signs*

The C.C.I.R. was represented by an observer at a recent meeting of the IEC Technical Committee No. 25 on letter symbols and signs, because radio wave propagation was on the agenda of the meeting and is to be the subject of an IEC publication.

4.3 *Miscellaneous*

Recommendation 431-1, advocating the adoption of a "Nomenclature of the frequency and wavelength bands used in radiocommunications", was maintained.

Resolution 22, "Coordination of the work of the C.C.I.R. and of other organizations on unification of means of expression", was kept unchanged, owing to its continuing interest.

ANNEX

RECAPITULATORY LIST OF TEXTS DEALING WITH TERMINOLOGY

1. List of C.C.I.R. texts containing definitions of terms

Volume	Study Group	Text	Title (with remarks in brackets)
I	1 – *Spectrum utilization and monitoring*		
		Recommendation 166-1	Unit of quantity of information
		Recommendation 325	Definition of the terms: emission, transmission and radiation
		Recommendation 326-1	Power of radio transmitters (Terms concerning emissions)
		Recommendation 331-2	Noise and sensitivity of receivers (maximum usable sensitivity)
		Recommendation 332-2	Selectivity of receivers (modulation acceptance band)
		Recommendation 341	The concept of transmission loss in studies of radio systems
		Recommendation 432-1	Classification and designation of emissions
		Question 16/1	Radio frequency dynamic range of a receiver
III	3 – *Fixed service at frequencies below about 30 MHz*		
		Recommendation 162-1	Use of directional antennae in the bands 4 to 28 MHz (directivity gain)
		Recommendation 342-2	Automatic error-correcting system for telegraph signals transmitted over radio circuits
		Recommendation 345	Telegraph distortion
	CIV – Vocabulary		
		Report 321	Terms and definitions (right-hand (clockwise) or left-hand (anti-clockwise) elliptically or circularly polarized (electromagnetic) waves).
IV Part 2	4 – *Fixed service using communication satellites*		
		Recommendation 445	Definitions concerning radiated power
		Report 204-2	Terms and definitions relating to space radiocommunications
		Report 213-2	Factors affecting multiple access in communication-satellite systems

Volume	Study Group	Text	Title (with remarks in brackets)
II Part 1	5 – *Propagation in non-ionized media*		
		Recommendation 310-2	Definitions of terms relating to propagation in the troposphere
		Recommendation 369-1	Definition of a basic reference atmosphere
II Part 2	6 – *Ionospheric propagation*		
		Recommendation 373-2	Definitions of maximum transmission frequencies
IV Part 1	9 – *Fixed service using radio-relay systems*		
		Report 378-1	Radio-relay systems for the transmission of pulse-code modulation and other types of digital signals
V Part 1	10 – *Broadcasting service (sound)*		
		Recommendation 447	Signal-to-interference ratios in amplitude-modulation sound broadcasting
	10/11 – *Broadcasting service (sound)/Broadcasting service (television)*		
		Report 471	Space services for broadcasting terminology

2. Other texts of Study Groups apart from the CIV of interest to the CIV

Volume	Study Group	Text	Title (with remarks in brackets)
III	7 – *Standard frequencies and time signals*		
		Resolution 52	Forms of expression for use in the standard-frequency and time-signal service (Question 1/7)
IV Part 1	9 – *Fixed service using radio-relay systems*		
		Study Programme 5-1C/9	Radio-relay systems for telephony and television – System reliability terminology

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SECTION CIV A: GRAPHICAL SYMBOLS

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 461

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

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

CONSIDERING

(a) that the Joint CCI/IEC Committee for the preparation of a publication for the international standardization of general graphical symbols for telecommunications, was set up following the agreement confirmed by the C.C.I.R. in Resolution 23;

(b) that a number of lists of graphical symbols were prepared by the Joint CCI/IEC Working Party and now appear in final form in the IEC publications;

(c) that, in accordance with § 6 of C.C.I.R. Report 335, Oslo, 1966, the symbols in lists already published by the IEC, which are of special interest to the C.C.I.R., should be published in the form of a C.C.I.R. Recommendation;

UNANIMOUSLY RECOMMENDS

that the symbols referred to in Report 440, New Delhi, 1970, be adopted as C.C.I.R. symbols.

REPORT 335-1*

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

(Resolution 23)

(1966 - 1970)

1. The Joint CCI/IEC Committee for the preparation of a publication for the international standardization of general graphical symbols for telecommunications was set up following the agreement confirmed by the C.C.I.R. in Resolution 23.

2. **Composition of the Joint Working Party**

The Joint CCI/IEC Working Party on graphical symbols for telecommunications has Mr. S.J. Aries (United Kingdom) as Chairman, and Mr. Bondesson (Sweden) as Secretary. The Working Party comprises 12 members, six representing the IEC, three the C.C.I.T.T., and three the C.C.I.R. The C.C.I.R. representatives are:

Mr. Amos (United Kingdom)
Mr. Durán (Spain)
Mr. Ferrari-Toniolo (Italy)

An engineer from the C.C.I.R. Secretariat and one from the C.C.I.T.T. attend the meetings.

3. The lists of symbols prepared by the Joint Working Party, which are to be submitted to participants in the work of the C.C.I.R. Interim Study Group on Vocabulary (CIV), are limited to those symbols which are of direct interest to the work of the C.C.I.R.

4. **Documents, 1966–1969, discussed at the Geneva, 1969 meeting**

Docs. XIV/1 and XIV/11, § 2 (C.C.I.R. Secretariat).

5. The results of the work done by the Joint Working Party are given in § 2, Doc. XIV/11, 1966–1969. Interim Study Group on Vocabulary (CIV) agrees generally with the proposed symbols. As the final amendments have not yet been made known to the C.C.I.R., it is considered that all of the symbols in § 2, Doc. XIV/11, 1966–1969, can be accepted by the C.C.I.R., only after they have been published by the IEC.

6. Interim Study Group on Vocabulary (CIV) considers that the object of this work is the publication by the IEC of all the symbols. Furthermore, symbols in this list of special interest to the C.C.I.R. may be published in the form of a C.C.I.R. Recommendation. The lists already published by the IEC which contain symbols of interest to the C.C.I.R. are the subject of Recommendation 452.

7. Approval of symbols published by the IEC is subject to the proviso that they cannot be revised without appeal to the Joint Working Party which has been charged with their preparation.

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* This Report was adopted unanimously.

REPORT 335-2

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

(Resolution 23)

(1966 - 1970 - 1972)

1. The Joint CCI/IEC Committee for the preparation of a publication for the international standardization of general graphical symbols for telecommunications was set up following the agreement confirmed by the C.C.I.R. in Resolution 23.

2. Composition of the Joint Working Party

The Joint CCI/IEC Working Party on graphical symbols for telecommunications has Mr. S.J. Aries (United Kingdom) as Chairman, and Mr. Nordelöf (Sweden) as Secretary. The Working Party comprises 12 members, six representing the IEC, three the C.C.I.T.T., and three the C.C.I.R. The C.C.I.R. representatives are:

Mr. Amos (United Kingdom)
Mr Durán (Spain)
Mr. Ferrari-Toniolo (Italy)

An engineer from the C.C.I.R. Secretariat and one from the C.C.I.T.T. attend the meetings.

3. The lists of symbols prepared by the Joint Working Party, which are to be submitted to participants in the work of the C.C.I.R. Interim Study Group on Vocabulary (CIV), are limited to those symbols which are of direct interest to the work of the C.C.I.R.

4. Documents, 1970-1973, discussed at the Interim Meeting, Geneva, 1972

5. The results of the work done by the Joint Working Party are given in Doc. CIV/1, 1970-1973. The Interim Study Group on Vocabulary (CIV) agrees with the proposed symbols. As the final amendments for all the lists of symbols have not yet been made known to the C.C.I.R., it is considered that all of the symbols mentioned in § 2, Doc. CIV/1, 1970-1973, can be accepted by the C.C.I.R. only after they have been published by the IEC.

6. Interim Study Group on Vocabulary (CIV) considers that the object of this work is the publication by the IEC of all the symbols. Furthermore, symbols in this list of special interest to the C.C.I.R. may be published in the form of a C.C.I.R. Recommendation. The lists already published by the IEC which contain symbols of interest to the C.C.I.R. are the subject of Draft Recommendation 461 (Rev. 72).

7. Approval of symbols published by the IEC is subject to the proviso that they cannot be revised without appeal to the Joint Working Party which has been charged with their preparation.

REPORT 440

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

Graphical symbols prepared by the Joint CCI/IEC Working Party and appearing in definitive form in IEC publications

(Resolution 23)

(1970)

This Report, which was adopted unanimously, has been published separately.

REPORT 440-1

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

Graphical symbols prepared by the Joint CCI/IEC Working Party and appearing in definitive form in IEC publications

(Resolution 23)

(1970 – 1972)

This Report has been published separately.

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SECTION CIV B: VOCABULARY

RECOMMENDATIONS AND REPORTS

Recommendations

There are no Recommendations in this section.

Reports

REPORT 321*

TERMS AND DEFINITIONS

Right-hand (clockwise) or left-hand (anti-clockwise) elliptically or circulary polarized (electro-magnetic) waves

(Resolution 21-1)

(1963)

It has become clear that the definitions found in the main existing publications (British Standards Institution, B.S. 204, 1960: Nos. 51 009 and 51 010; – Institution of Radio Engineers 1950; – International Electrotechnical Commission, Draft 1/60 (Secretariat) 281: Nos. 60.20.030 and 60.20.035) on the direction of rotation of the electric field vector in waves elliptically or circularly polarized, might be easily misunderstood, with serious practical consequences, especially at a time when space communications are being developed.

Doc. 108 (U.K.), Geneva, 1963, points out the causes of ambiguity and offers solutions. The following definitions have been drafted to avoid any danger of ambiguity in future.

1. Right-hand (clockwise) polarized wave

An elliptically or circularly-polarized wave, in which the electric field-intensity vector, observed in any *fixed plane*, normal to the direction of propagation, whilst looking in (i.e. not against) the direction of propagation, rotates *with time* in a *right-hand* or clockwise direction.

Note. — For circularly-polarized plane waves, the ends of the electric vectors drawn from any points along a straight line normal to the plane of the wave front, form, *at any instant*, a *left-hand* helix.

2. Left-hand (anti-clockwise) polarized wave

An elliptically or circularly-polarized wave, in which the electric field-intensity vector, observed in any *fixed plane*, normal to the direction of propagation, whilst looking in (i.e. not against) the direction of propagation, rotates *with time* in a *left-hand* or anti-clockwise direction.

Note. — For circularly-polarized plane waves, the ends of the electric vectors drawn from any points along a straight line normal to the plane of the wave front, form, *at any instant*, a *right-hand* helix.

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* This Report was adopted unanimously.

REPORT 441*

COOPERATION ON AN EQUAL FOOTING BETWEEN THE INTERNATIONAL CONSULTATIVE COMMITTEES AND THE INTERNATIONAL ELECTROTECHNICAL COMMISSION ON WORK RELATING TO VOCABULARY

(Resolution 21-2)

(1970)

The following is submitted as the initial report on the cooperative relations referred to in the title above. It supplements Resolution 21-2, as indicated in the last few lines of the Annex to the Resolution. This Report will be brought up to date in each new edition of the C.C.I.R. documents.

1. Brief information on the working procedure of IEC** Technical Committee No. 1 (Terminology) in preparing the IEV***

The IEV is at present in its *second edition* and consists of a collection (now almost complete) of booklets each containing a chapter (so far called a "group") of the Vocabulary. It represents a revision, carried out over a period of some twenty years, of the *first edition* which dates back to before the war and was much less extensive (it consisted of one relatively slim volume).

IEC Technical Committee No. 1 undertook the revision of the second edition on the following bases:

1.1 The *third edition* of the IEV will consist of a greater number of chapters, often dealing with more limited subjects. Each chapter will be the subject of a separate publication, the revised editions of which will be produced as required independently of the revision of other chapters.

1.2 Generally speaking, IEC Technical Committee No. 1 entrusts the *drafting* of the different chapters to the *IEC Technical Committees concerned*, i.e.:

- either to a group of experts forming a vocabulary sub-committee of one Technical Committee;
- or to a group of experts appointed by several Technical Committees concerned with the same subject matter who constitute a working group of Technical Committee No. 1.

1.3 For certain fields of interest to *international organizations other than the IEC* – lighting or telecommunications, for example – agreements may be concluded between these organizations and the IEC on cooperation, under agreed conditions, in preparing drafts and on the manner in which each of the contracting parties may use them to the best advantage.

1.4 In all cases, Technical Committee No. 1 acts as the central body, which is the role conferred upon it by the IEC. It is responsible for ensuring that the IEV, as a whole, is consistent and satisfactory. It is bound, like all other Technical Committees of the IEC to follow the *procedure* adopted for each draft (whether it is a chapter of vocabulary, test specifications or any other type of text) for it to become an official IEC document (preliminary consultation with the National Committees, analysis, formulation, fresh consultation, etc.).

2. Scope of the agreement on cooperation between the C.C.I.s and the IEC and method of implementation

2.1 Under the terms of this agreement, its *scope* covers the telecommunication vocabulary contained in present Publications 55 (telegraphy and telephony) and 60 (radio) of the IEV.

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* This Report was adopted unanimously.

** International Electrotechnical Commission.

*** International Electrotechnical Vocabulary.

It is, of course, understood that the planned revision of the third edition will be extremely thorough and that the contents will be divided into some ten or twelve chapters of reasonable length and homogeneous contents.

The agreement may possibly be broadened to cover other subjects in which the C.C.I.s have already shown interest (or may do so in the future), such as recording (§ 2.9 of Doc. XIV/15, 1966-1969) or reliability (§ 2.10 of Doc. XIV/15, 1966-1969) which for the time being are dealt with by IEC Technical Committee No. 60 and Technical Committee No. 56 respectively (as mentioned in § 1.2 above). But the "dialogue" made possible by the implementation provision introduced for the telecommunication vocabulary (mentioned in the preceding paragraph) should greatly facilitate the possibility of agreement in such cases.

2.2 The implementation provision could be considered to consist of two stages: first, ten or twelve *working groups* appointed to draft the various chapters (§ 2.1, first paragraph) and consisting of *experts specializing* in the subjects concerned; supervising them is an organ called the *Joint Coordination Group (J.C.G.)*, which is responsible for the satisfactory conduct of the work as a whole.

The general lines of the *terms of reference of the J.C.G.* are described in the summary record of the meeting of IEC Technical Committee No. 1 held at The Hague in December 1968 (pink document, P.V. 1182/TC 1) as follows (provisional translation): "The IEC and the C.C.I.R. officially confirmed their agreement to establish a Joint IEC/I.T.U. Coordinating Group, a group with equal representation, the Chairman and the Secretary to be elected from each of the two parties, the Chairman from the I.T.U. and the Secretary from the IEC. Its task would be to fix a plan of work, to determine the division into chapters, to establish for each chapter a joint expert group, not necessarily with equal representation, responsible for drafting it and to ensure coordination of the activities of those expert groups and any arbitration that might be necessary."

The equal membership of the J.C.G. (6 representatives of the IEC and 6 representatives of the two C.C.I.s: see Doc. XIV/16, 1966-1969) expresses the concern for equality of prerogatives and responsibilities of the two contracting organizations. The same concern is evident in the assignment of the executive offices foreseen for two members of the J.C.G.: the office of secretary was entrusted to an IEC representative (Technical Committee No. 1 appointed its own secretary to this position) while the chairmanship was entrusted to a representative of the C.C.I.'s (C.C.I.R. Study Group XIV was asked in Doc. XIV/16 to make this appointment and chose its own Chairman – see Doc. XIV/21, 1966-1969).

Under these terms of reference, the J.C.G., at its first meeting (16 and 17 October 1969), will have to decide how it may best discharge its responsibilities and prepare the plan of work, the first requirement of which is to plan the distribution of chapters of the telecommunication vocabulary at least in part. This distribution is clearly a precondition for the creation of the necessary groups of experts and for considering the recommendations to be given to each of these groups. All of this work obviously requires the agreement of all twelve members.

The groups of experts will also have members of both organizations but the numbers will not necessarily be equal. It is clear that the number of experts it will be possible to obtain from the C.C.I. Study Groups and from the IEC Technical Committees for a particular chapter will depend on the degree of interest in it. But, on the average, the numbers of representatives will probably be equal, although this consideration is much less important at expert group level than at J.C.G. level.

3. Position of the C.C.I.R. and the role of Interim Study Group on Vocabulary (CIV) in relation to the implementation arrangement

3.1 Having emphasized, in the foregoing, the principle of parity which is the essential feature of the agreement, it is advisable to review the implications for the Interim Study Group on Vocabulary (CIV). The success of the experiment clearly demands that the working procedures of the two contracting organizations (the IEC, on the one hand, and the two C.C.I.s on the other hand) should be *compatible* and that they should be mutually respected. The C.C.I.R. will be justified in insisting on its own requirements to the extent that it does not make any demands which would prejudice the rules normally followed by Technical Committee No. 1. The balance to be achieved in this respect should guide all activities of the J.C.G., which has no authority over IEC Technical Committee No. 1, C.C.I.R. Interim Study Group on Vocabulary (CIV) or C.C.I.T.T. Study Group VII, but must regard itself as their joint representative.

3.2 The vocabulary requirements of the C.C.I.R. are essentially those of its Study Groups, each of which works within its terms of reference, and the aim of the Interim Study Group on Vocabulary (CIV) has always been – and is even more so today – to meet these requirements. It will now be in a better position to do so. Two serious shortcomings have unfortunately been evident for many years:

— first, the lack of a basic vocabulary with satisfactory definitions of the terms currently used in the field of radio;

— second, the absence of practical means to influence the preparation of this vocabulary by introducing new concepts and the corresponding terms or changes and improvements in the definitions of existing terms which are adopted by each study group in the course of its work.

3.3 The cooperation arrangements now introduced should put an end to this state of affairs. This should be possible through the C.C.I. representatives who act as members of the J.C.G. and as experts in the working groups set up to draft the chapters of the IEV. The C.C.I.R. representatives will be able to create a dual channel through which the twofold problem mentioned in the preceding paragraph may be solved:

— on the one hand, an incoming channel through which the C.C.I.R. will be kept informed of the progress accomplished on the different chapters, from the preliminary draft through the various stages; Interim Study Group on Vocabulary (CIV) unanimously expressed the wish that copies of these preliminary drafts should be sent to the members of Interim Working Party CIV/1 to every "national collaborator" and to the appropriate "specialized collaborators" (who, so far as the study groups which set up standing vocabulary groups are concerned, will be the members of these groups);

— on the other hand, an outgoing channel consisting of the terminology formulated by the various study groups; as each of these contributions will thus be brought to the attention of the appropriate group of experts without delay, there will be no danger of their being omitted because the group did not know of their existence or received them too late, with the result that they contain discrepancies. This outgoing channel will also include all the comments which the C.C.I.R. (mainly through Interim Working Party CIV/1) may wish to make on information received through the incoming channel.

The role of Interim Study Group on Vocabulary (CIV) in this arrangement would appear to be of cardinal importance: to ensure, through the provisions adopted at its meetings and the continuing action of its Interim Working Party CIV/1 and with the assistance of the C.C.I.R. Secretariat that difficulties are settled and that the necessary speed, reliability and efficiency are achieved.

SECTION CIV C: OTHER MEANS OF EXPRESSION

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 430

UNIT SYSTEMS*

The C.C.I.R., (1953 – 1963)

CONSIDERING

(a) that the use of the rationalized MKSA system (also known as the rationalized Giorgi system), has been recommended by the International Electrotechnical Commission (Technical Committee No. 24 meeting, held in Paris on 17 and 18 July, 1950) and that it is now very widely used by radio engineers and by the authors of radio publications;

(b) that the C.C.I.T.T. recommended the use of this system, at its IInd Plenary Assembly, New Delhi, 1960, in its Recommendation B.3 (an amended version of the former C.C.I.F. Recommendation 6);

(c) that the Administrative Radio Conference, Geneva, 1959, itself, in Recommendation No. 9, supported the gradual adoption of the system, in particular on the grounds of its use by the C.C.I.R.;

UNANIMOUSLY RECOMMENDS

that Administrations and private operating agencies should make every effort, in their relations with the I.T.U. and its permanent organs, and most particularly with the C.C.I.R., to bring about a generalized and exclusive adoption of the unit system (comprising those units which, in the system referred to by the International Weights and Measures Commission as the *international unit system*, concern geometry, mechanics, electricity and magnetism), known as the MKSA or the GIORGI system and incorporating the use of the *rationalized form* of the electrotechnical relations.

RECOMMENDATION 431-1

NOMENCLATURE OF THE FREQUENCY AND WAVELENGTH BANDS USED IN RADIOCOMMUNICATIONS

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

CONSIDERING

(a) that the merits of Heinrich Hertz (1857-1897), as a research worker on the basic phenomena of radio waves, are universally recognized, as was confirmed at the centenary of his birth, and that as early as 1937 the IEC adopted the hertz (symbol: Hz) as a name for the unit of frequency (see, *inter alia*, Publication 27, 1966);

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* Note by the C.C.I.R. Secretariat: With regard to unit designation, it should be pointed out that, during the 9th plenary session of the XIth Plenary Assembly of the C.C.I.R., it was unanimously decided that in future C.C.I.R. publications, the abbreviation for "decibel" would be "dB".

(b) that the C.C.I.T.T. also uses the hertz (see white Book, Tome I, Recommendation B. 1);

(c) that the Table in this Recommendation should be as synoptic as possible and that the expression of frequencies should be as concise as possible;

UNANIMOUSLY RECOMMENDS

1. that the hertz (Hz) be accepted for use in publications of the I.T.U., as the name for the unit of frequency;

2. that Administrations should always use the nomenclature of the frequency and wavelength bands given in No. 112 of the Radio Regulations, Geneva, 1959, except in those cases where this would inevitably cause very serious difficulties.

ANNEX

Band number	Frequency/range (lower limit exclusive, upper limit inclusive)	Corresponding metric sub-division
4	3 to 30 kHz	Myriametric waves
5	30 to 300 kHz	Kilometric waves
6	300 to 3000 kHz	Hectometric waves
7	3 to 30 MHz	Decametric waves
8	30 to 300 MHz	Metric waves
9	300 to 3000 MHz	Decimetric waves
10	3 to 30 GHz	Centimetric waves
11	30 to 300 GHz	Millimetric waves
12	300 to 3000 GHz or 3 THz	Decimillimetric waves

Note 1. — "Band number *N*" extends from 0·3 × 10^N to 3 × 10^N Hz.

Note 2. — Abbreviations:

Hz = hertz

k = kilo (10^3), M = mega (10^6), G = giga (10^9), T = tera (10^{12})

Note 3. — Abbreviations for adjectival band designations:

band 4 : VLF
band 5 : LF
band 6 : MF
band 7 : HF
band 8 : VHF
band 9 : UHF
band 10 : SHF
band 11 : EHF

CIV C: *Reports*

There are no Reports in this section.

QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS (CIV)

There are no Questions or Study Programmes concerning the work of the CIV.

RESOLUTION 21-2

TERMS AND DEFINITIONS

(1963 - 1966 - 1970)

The C.C.I.R.,

CONSIDERING

(a) that it is important, for ease and efficiency of the work of the I.T.U. and of the C.C.I.s, that means of expression of all kinds (terms, symbols, etc.) and the conditions of their use be rendered and maintained as uniform as possible, also for the use of other interested organizations;

(b) that the I.T.U. Administrative Council has recommended, in its Resolution 283, that a "List of definitions of essential telecommunication terms", known hereafter as the List, should be compiled. Part I of this List, "General terms telephony, telegraphy", has been published by the I.T.U. and is now being revised by Study Group VII of the C.C.I.T.T.; Part II, relating to radiocommunications, and for which the C.C.I.R. is responsible, has yet to be prepared;

(c) that, at its XIth Plenary Assembly, the C.C.I.R. confirmed the need for such a work to be based on efficient cooperation with any organization engaged in vocabulary matters in all or part of the same technical sphere, and above all with the International Electrotechnical Commission (IEC), whose Technical Committee No. 1 has been working for several years on a chapter in its "International Electrotechnical Vocabulary" devoted to radiocommunications, as a means of avoiding, unless necessary, real or apparent contradictions between the conventions respectively adopted;

(d) that the IEC has prepared a document standardizing terms of radiocommunications in French and in English (Doc. XIV/1, Geneva, 1963), as a revision of the second edition;

(e) that the IEC, the C.C.I.R. and the C.C.I.T.T. have agreed to join in this work by setting up a joint IEC/I.T.U. coordination group with an equal number of I.T.U. (C.C.I.T.T. and C.C.I.R.) representatives and IEC representatives, and additionally setting up working groups of experts;

(f) that, during the meetings of Study Group XIV before the XIIth Plenary Assembly, a final draft list of corresponding terms was produced in the following languages: French, English, Spanish, Russian and German, on the basis of the IEC document under *(d);*

(g) that the International Working Party XIV/2 (created by the XIth Plenary Assembly) made a valuable contribution to the terms and definitions relative to reliability;

UNANIMOUSLY DECIDES

1. that the work on the List of Definitions, Part II, relating to radiocommunications, recommended by the I.T.U. Administrative Council in its Resolution 283, which has already started, should be continued by the Interim Working Party CIV/1, using the work of the expert working groups, with the assistance of the Joint IEC/CCIR - CCITT Coordination Group of the C.C.I.

2. that the members collaborating in the Interim Working Party CIV/1 shall be:

— "specialized collaborators" appointed by the respective Chairmen of the other Study Groups of the C.C.I.R., each Study Group Chairman being responsible for appointing as many persons as necessary for good cooperation, and these same persons would be qualified to work (and qualified to represent the C.C.I.R.) in the expert groups formed by the Joint IEC/CCIR - CCITT Coordination Group;

— "national collaborators", one of each Administration, deciding to participate in the work of terminology. The name of the national collaborator should be communicated to the C.C.I.R. Secretariat and to the Chairman of the Interim Working Party CIV/1;

3. that as a first step the Joint Coordination Group will inform the Interim Working Party CIV/1 of the sub-division of the List;

4. that the Chairman of Interim Study Group on Vocabulary (CIV), in coordination with the Joint Coordination Group, should ask the expert groups to prepare the lists of terms and definitions with an unequivocal system of numbering of the concepts (which will be the provisional IEC numbering of the last print (see Annex));

5. that the members of the Interim Working Party CIV/1 receive the terms and definitions collected by the Interim Study Group on Vocabulary (CIV) and by the Joint Coordination Group with a request for their comments within a specified time;

6. that for the purpose of the C.C.I.R. it would be necessary to publish the result *every two years* in a suitable form; the terms in all available languages; the definitions only in English and French in the first instance. If discrepancies appear which cannot be solved rapidly, the two or more definitions should be presented stating the restricted field of application in which each particular definition is used (see Annex);

7. that the first edition should be studied by the Administrations and especially by the members of the Interim Working Party CIV/1 for the purpose of preparing a second edition. In the first edition, footnotes and other remarks regarding the terms may be helpful.

8. that the final aim of the work should include corresponding terms and definitions in all official I.T.U. languages. In addition, the corresponding terms (but not their definitions) should be given ultimately also in other languages important for international telecommunication work.

ANNEX

1. Taking into account the directives of the C.C.I.R. given under §§ 4 and 6 of the Resolution, it is suggested that definitions received by the Joint Coordination Group be classified as follows:

Category A

The proposed definition is substantially identical to each of the background definitions.* This is agreed and denoted by the symbol CA.

Category B

The term has different meanings, or different shades of meaning, in special fields; this is indicated by parenthetical labels preceding each separate definition. These will be CB_1, CB_2, CB_3 ... thus indicating an order of paragraphs to follow the common term.

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* It is suggested that the Joint Coordination Group shall take the initiative in collecting background material as a tool to be used by the Working Parties. Sources of "background" definitions are already available in Russian, German, English and French. There are many additional sources.

Category Bx

The subject term, in present context, has reference to a new usage of an already familiar term. This term will be referred to an appropriate working party who will be asked to provide an additional definition to be inserted in sequence with the symbols B_1, B_2... B_{x-1} already in use.

Category C

The proposed definitions and the background definitions have identical technical meanings, but they differ substantially in method of expression (quite apart from language of origin).

In general, the definition likely to be most useful to the average reader will be selected and indicated by the symbol CC.

In very rare instances, it is found that two definitions, identical in meaning, may be expressed in different forms.

(Example: three-dimensional graphic representation, as an alternate to a purely mathematical approach, with reference to stability criteria of servo-mechanisms.)

In these rare instances, it is proposed that the two equivalent texts of the same definition be represented by the symbols CC_1, CC_2.

Category D

If it is found from the group of incoming definitions and the equivalent background definitions that two definitions are identical in meaning but differ moderately in language, it is proposed that a simple merger of the two would be more informative than either individual definition.

Example 1. — A particular expressive adjective is borrowed from one definition and added to the adjectives already present in the other.

Example 2. — A definition, say *b*, would be a very useful explanatory footnote for definition of say *a*.

We recommend the merger by the use of symbol CD.

Category E

The "background" list of definitions has been carefully checked and there is no evidence that this subject term has ever been defined. Therefore, by the symbol "CE" this term is referred to an appropriate working party to generate a new definition.

Category F (rarely necessary)

It is found that the subject term has been elsewhere defined, with the meaning here intended. However, it is found that the phraseology of all available published definitions are seriously defective in that they invite needless confusion in the mind of the reader. Therefore, by the symbol "CF" this term is referred to an appropriate working party for thorough editing.

Other categories may, of course, be developed as the need arises. The proposed systematic framework of thought is an attempt to avoid much wasted effort.

2. The attention of the members of the Interim Working Party CIV/1 should be drawn to the information and guidelines contained in Report 441. This Report will be brought up to date in each edition of the Volumes of the C.C.I.R.

RESOLUTION 22

COORDINATION OF THE WORK OF THE C.C.I.R. AND OTHER ORGANIZATIONS ON UNIFICATION OF MEANS OF EXPRESSION

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

CONSIDERING

(a) that it is important, for the ease and efficiency of the work of the C.C.I.s, that means of expression of all kinds (terms, symbols, etc.), and the conditions of their use, be rendered and maintained as uniform as possible;

(b) that the desired unification means avoiding, unless imperatively necessary, real or apparent contradictions between the conventions accepted by the C.C.I.R. and those used by other qualified organizations, especially the International Electrotechnical Commission (IEC);

(c) that the subjects open to study, as regards the means of expression, may be of very unequal practical importance from the standpoint of C.C.I.R. needs, and that it is natural that the choice of subjects to be dealt with and the amount of time and effort to be devoted should be decided upon according to the degree of importance, bearing in mind the rather limited means available, entailing the risk of further delaying the already, of necessity, slow advancement of the most important tasks;

(d) that, as regards C.C.I.R. needs, most Administrations consider a decimal classification to be of little use, and that Question 72, initiated at the VIth Plenary Assembly, Geneva, 1951, at the instigation of the International Federation of Documentation (F.I.D.), has remained in abeyance, without any result other than the unimplemented proposal contained in Report 95 (Warsaw, 1956), issued as a supplement to Report 37 (London, 1953);

UNANIMOUSLY DECIDES

1. that the C.C.I.R., moved by a constant concern to ensure coordination with other competent organizations dealing with terminology on the same subjects, is anxious to examine the question of means of expression answering its own particular needs. According to the degree of importance of such needs and depending on circumstances, in some cases, no more than a mere contact consisting of an exchange of information or documents will be required, while in others, a close cooperation will be needed, with a view to achieving practical results and efficiency not only at the final stage of the work but also, if possible, at the different preparatory stages;

2. that the C.C.I.R. is prepared, if necessary, to accept proposals for participation in the work of mixed Study Groups, set up in collaboration with other organizations. If such proposals are received long before the date of the next Plenary Assembly, the Director, C.C.I.R., and the Chairman, Interim Study Group on Vocabulary (CIV) shall jointly assess, according to the urgency of the proposals and the interest they present, whether they merit consultation by correspondence with the Administrations taking part in the work of that Study Group;

3. that, as regards the classification in which the F.I.D. is concerned, the study of Question 72 has been terminated and Reports 37 and 95, arising from that Question, have been cancelled. These arrangements, of course, enable the F.I.D. to keep the C.C.I.R. informed of the progress made in its work, if it should wish to do so.

RESOLUTION 23

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATIONS

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

CONSIDERING

(a) that it is important, for the ease and efficiency of the work of the C.C.I.s, that means of expression of all kinds (terms, symbols, etc.), and the conditions of their use, be rendered and maintained as uniform as possible;

(b) that the desired unification means avoiding, unless imperatively necessary, real or apparent contradictions between the conventions accepted by the C.C.I.R. and those used by other qualified organizations, especially the International Electrotechnical Commission (IEC), and that actual and efficient cooperation must be secured for this purpose;

(c) that the IEC, having to prepare a document standardizing general graphical symbols for telecommunications to replace its Publication 42 entitled "International symbols (Part III): Graphical signs for weak current installations", which has not been revised since July 1939 (2nd edition), and is thus out of date, has proposed that the C.C.I.T.T. and the C.C.I.R. should join in this work by setting up a joint IEC/I.T.U. Committee, with an equal number of I.T.U. (C.C.I.T.T. and C.C.I.R.) representatives and IEC representatives;

(d) that the C.C.I.T.T. decided to accept this proposal at its IInd Plenary Assembly, New Delhi, 1960 (Minutes of the VIIIth Plenary Meeting, Doc. AP/II/90);

(e) that, the IEC and the C.C.I.T.T. having scheduled the first meeting of the Joint Committee for late 1962 or early 1963, the Director, C.C.I.R., consulted Administrations taking part in the work of the C.C.I.R. Study Group XIV by Circular G XIV/154 (27 August 1962), on the reply to be given to the IEC proposal;

(f) that all the replies from Administrations to this consultation Circular were in favour of C.C.I.R. participation in the Joint Committee and that the three places reserved for the C.C.I.R. in its membership have been filled, thanks to nominations proposed by the Administrations of France*, Italy and the United Kingdom;

UNANIMOUSLY DECIDES

that the C.C.I.R. confirms its agreement to take part in the work of the Joint IEC/I.T.U. Committee, set up at the proposal of the IEC, for the preparation of a publication for the international standardization of general graphical symbols for telecommunication. The three C.C.I.R. representatives on this Joint Committee will find general directives for their participation in the note annexed to the consultation Circular mentioned in § *(e)*. They will keep the Director, C.C.I.R., and the Chairman, Interim Study Group on Vocabulary (CIV), informed of the progress of the work.

RESOLUTION 54

TERMS AND DEFINITIONS RELATING TO SOUND AND VIDEO RECORDING

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

CONSIDERING

(a) that account has to be taken of the development of sound and video recording techniques and the fact that a vocabulary is urgently needed in these fields, in particular with a view to the establishment of standards for the international exchange of programmes;

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* The member designated by the Administration of France has been replaced by a member designated by the Administration of Spain (see Report 335-1).

(b) that it is necessary to take into consideration the work on the vocabulary of recording being carried out by other international organizations, in particular the International Electrotechnical Commission (Technical Committees Nos. 1 and 60), and also, for example, the European Broadcasting Union and the International Radio and Television Organization;

(c) that a Joint IEC/CCIR-CCITT Coordination Group has been set up to coordinate work on vocabulary in the field of telecommunications;

UNANIMOUSLY DECIDES

1. that an Interim Working Party of the Interim Study Group on Vocabulary (CIV) be set up to contribute to the establishment and keeping up to date of terms and definitions relating to sound and video recording;
2. that this Interim Working Party shall conduct its work, in cooperation with the Chairman of the Interim Study Group on Vocabulary (CIV), taking into account the existence of the Joint IEC/CCIR/CCITT Coordination Group and the methods of work established by the Interim Study Group on Vocabulary (CIV);
3. that this work shall by carried out by correspondence as far as possible.

Note. — When this Group was set up, the Administrations of the following countries announced their intention of participating in its work:

Spain
Federal Republic of Germany
U.S.S.R.

The Interim Working Party will work under the chairmanship of Mr. N. Chistiakov (U.S.S.R.), Ministry of Posts and Telecommunications, 7 Gorky Street, Moscow.

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