INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

DOCUMENTS OF THE

XIth PLENARY ASSEMBLY

OSLO, 1966

VOLUME I

EMISSION
RECEPTION
VOCABULARY

Published by the
INTERNATIONAL TELECOMMUNICATION UNION
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DISTRIBUTION OF THE TEXTS OF THE XIth PLENARY ASSEMBLY OF THE C.C.I.R. AMONG VOLUMES I–VI

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

1. Recommendations

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[1] Published separately.

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

(Oslo, 1966)

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

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

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

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Rec. 205-1	Synchronized transmitters for HF broadcasting	V
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RECOMMENDATIONS OF SECTION A (EMISSION)

RECOMMENDATION 325

DEFINITIONS OF THE TERMS EMISSION, TRANSMISSION AND RADIATION

(Question 1/I, § 4)

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

CONSIDERING

(a) that Recommendation No. 8 (Question 1/I) of the Administrative Radio Conference, Geneva, 1959, requested the C.C.I.R. to define the terms: Emission, Transmission and Radiation;

(b) that some divergence in meaning of these terms, as normally used in English on the one hand and in French and Spanish on the other is evident, and that better agreement on definitions may be achieved by taking account of other terms;

UNANIMOUSLY RECOMMENDS

that the following definitions be employed in I.T.U. texts concerning radiocommunication:

Rayonnement (radioélectrique) 1. Transport d'énergie sous forme d'ondes radioélectriques à partir d'une source. 2. Energie se propageant dans un milieu sous forme d'ondes radioélectriques.	*Radiation (in radiocommunication)* 1. The outward flow of radio-frequency energy from a source. 2. Energy flowing in a medium in the form of radio waves.	*Radiación (radioeléctrica)* 1. Transporte de energía, en forma de ondas radioeléctricas, a partir de una fuente. 2. Energía que se propaga en un medio en forma de ondas radioélectricas.
Emetteur (radioélectrique) Appareil produisant de l'énergie radioélectrique en vue d'assurer une radiocommunication.	*(Radio) Transmitter* Apparatus producing radio-frequency energy for the purpose of radiocommunication.	*Transmisor (radioeléctrico)* Aparato que genera energía radioélectrica con objeto de asegurar una radiocomunicación.
Ensemble émetteur (radioélectrique) Ensemble d'appareils comprenant un émetteur radioélectrique connecté à une ou plusieurs antennes ou plusieurs émetteurs connectés à une antenne commune.	*(Radio) Transmitting system* Apparatus comprising a radio transmitter connected to its antenna or antennae; also several transmitters connected to a common antenna.	*Sistema transmisor (radioeléctrico)* Conjunto de aparatos que comprende un transmisor radioeléctrico conectado a su antena o antenas, o bien varios transmisores conectados a una antena común.
Emission (en radiocommunication) Rayonnement produit, ou production de rayonnement, à partir d'un ensemble émetteur radioélectrique.	*Emission (in radiocommunication)* Radiation produced, or the production of radiation, by a radio transmitting system.	*Emisión (en radiocomunicación)* Radiación producida, o producción de radiación por un sistema transmisor radioeléctrico.

Note. – L'émission est considérée comme étant unique si le signal modulant et les autres caractéristiques sont les mêmes pour chacun des émetteurs de l'ensemble émetteur radioélectrique et si l'espacement entre antennes n'est pas supérieur à quelques longueurs d'ondes.

Note. – The emission is considered to be a single emission if the modulating signal and the other characteristics are the same for every transmitter of the radio transmitting system and the spacing between antennae is not more than a few wave lengths.

Nota. – La emisión se considera como simple emisión si la señal moduladora y otras características son las mismas para cada transmisor de un sistema transmisor radioeléctrico y la separación entre antenas no es mayor de unas pocas longitudes de ondas.

Transmission

Action de faire parvenir d'un point à un autre, soit directement, soit indirectement, matériellement ou par l'intermédiaire de signaux, un objet, un document, une image, un son ou des informations de toute nature.

Transmission

Action of conveying between two points, either directly or indirectly, by physical means or by signal, an object, document, picture or sound, or information of any nature.

Note. – The use of the word " transmission " in the sense of " emission " in radiocommunication is deprecated.

Transmisión

Acción de transportar entre dos puntos, sea directa o indirectamente, bien físicamente o por señales, un objeto, un documento, una imagen, un sonido o una información de cualquier naturaleza.

Nota. – Debe evitarse la utilización de la expresión « transmisión » en el sentido de « emisión » (en radiocommunicación).

RECOMMENDATION 326-1

POWER OF RADIO TRANSMITTERS

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

CONSIDERING

(a) that the Radio Regulations, Geneva, 1959, Article 1, No. 94, lay down that, when the power of a radio transmitter is referred to, it shall be expressed in one of the following terms:

- peak envelope power;
- mean power;
- carrier power;

but that indication of one only of these powers is adequate only for certain classes of emission and for certain uses, whereas in many cases it is desirable to express the transmitter power in other forms (see Appendix 1 of the Radio Regulations, Geneva, 1959);

(b) that the direct measurement of each of these powers, or the deduction of one of them from a measurement of another, can only be effected under very precisely defined operating conditions;

(c) that a specification of emitted power is advantageous for use in calculation of radio propagation, spacing between assigned frequencies, signal-to-interference ratios and signal-to-noise ratios involved in radiocommunication;

(d) that, to act as a basis for administrative regulations or for the calculations mentioned under § *(c)*, the relationships between values of power expressed in various terms with different types and levels of the modulating signal, must be known for each class of emission;

(e) that the automatic recorders, which may be used in monitoring emissions or measuring the field strength of received signals, more often indicate average, rather than peak field strength; and that, depending on the class of emission, this mean field intensity may or may not be affected by the modulation;

(f) that, consequently, it is always necessary for the field-strength, as measured by such equipment, to be interpreted before being related to the power of the transmitter;

(g) that Article 2 of the Radio Regulations Geneva, 1959, introduces a new classification of emissions and new terminology;

UNANIMOUSLY RECOMMENDS

1. Terminology and definitions

that the following terminology and definitions should be used in dealing with questions relating to the power of radio transmitters and to the relationships between the various forms of that power.

POWER

1.1 *Peak envelope power of a radio transmitter* (Radio Regulations, Geneva, 1959, Article 1, No. 95)

The average power supplied to the antenna transmission line by a transmitter during one radio-frequency cycle at the highest crest of the modulation envelope, taken under conditions of normal operation.

Note 1.1.1 – Applies to French text only.

1.2 *Mean power of a radio transmitter* (Radio Regulations, Geneva, 1959, Article 1, No. 96)

The mean power supplied to the antenna transmission line by a transmitter during normal operation, averaged over a time sufficiently long compared with the period of the lowest frequency encountered in the modulation. A time of 0·1s during which the mean power is greatest will normally be selected.

1.3 *Carrier power of a radio transmitter*

The average power supplied to the antenna transmission line by a radio transmitter during one radio-frequency cycle under conditions of no modulation; for each class of emission the condition of no modulation should be specified.

CARRIERS

1.4 *Full carrier*

Carrier emitted at a power level of 6 dB or less below the peak envelope power.

Note 1.4.1 – Double-sideband amplitude-modulated emissions normally comprise a full carrier with a power level exactly 6 dB below the peak envelope power at 100% modulation.

Note 1.4.2 – In single-sideband full-carrier emissions, a carrier at a power level of 6 dB below the peak envelope power is generally emitted, to enable the use of a receiver designed for double-sideband full-carrier operation.

1.5 *Reduced carrier*

Carrier emitted at a power level between 6 dB and 32 dB below the peak envelope power and preferably between 16 dB and 26 dB below the peak envelope power.

Note 1.5.1 – A reduced carrier is generally emitted to achieve automatic frequency control and/or gain control at the receiver.

1.6 *Suppressed carrier*

Carrier restricted to a power level more than 32 dB below the peak envelope power and preferably 40 dB or more below the peak envelope power.

INTERMODULATION

1.7 *Intermodulation component* (in a radio transmitter for amplitude-modulated emissions)

Sinusoidal oscillation produced in an imperfectly linear amplitude-modulated radio transmitter in response to sinusoidal oscillations applied at the input to the transmitter, the frequency of which is, at the output of the transmitter, the sum or difference of the frequencies of the normal sideband components resulting from the modulation of a carrier by the exciting oscillations, or the sum or difference of integral multiples of these frequencies.

The frequency of an intermodulation component at the output of the transmitter is given by the formula:

$$F = p\,(F_0 \pm f_1) \pm q\,(F_0 \pm f_2) \text{ with } p, q = 1, 2, 3 \ldots$$

where F_0 is the carrier frequency, f_1 and f_2 the frequencies of the exciting oscillations.

The positive sign between the two terms of the sum corresponds to much higher frequency oscillations with, as a general rule, very low amplitudes; this case is of minor interest for the purpose of this Recommendation.

1.8 *Intermodulation products* (for amplitude-modulated emissions)

All the intermodulation components produced in an amplitude-modulated transmitter in response to given sinusoidal oscillations applied to the input.

1.9 *Order of an intermodulation component* (in a radio transmitter for amplitude-modulated emissions)

Sum $n = p + q$ of the two positive integral coefficients determining the frequency of an intermodulation component at the output of an amplitude-modulated radio-transmitter with a given carrier frequency, as a function of the frequencies of two sinusoidal oscillations applied simultaneously at the input to the transmitter.

2. Relationships between the peak envelope power, the mean power and the carrier power of a radio transmitter

that in the following Tables, the conversion factors are given which can be used to relate the power of a radio transmitter, expressed in one of the forms defined above, to the power given in another of these forms.

The conversion factors are calculated on the basis of certain assumptions; these assumptions are explained in the notes following the Tables.

2.1 *Conversion factors with respect to the peak envelope power*

2.1.1 Table I gives the conversion factors applicable when the peak envelope power is taken asunity.

2.1.2 Column 5 gives the theoretical values of the mean power which would be obtained, with linear transmitters for amplitude modulation. In practice, the imperfect linearity of the transmitter and other causes may increase the mean power above the figures shown in the Table.

2.1.3 As the conversion factors depend on the modulating signal, one or more examples described in Column 2 have been chosen to enable representative values for the factors in Column 5 to be determined.

2.1.4 Similarly, Column 4 gives the theoretical carrier power in the specific conditions of no-modulation described in Column 3, and chosen so as to make that carrier power easily measurable.

2.1.5 Unless otherwise specified, the expression " sinusoidal oscillation " in this Recommendation means an audio-frequency periodic sinusoidal oscillation.

TABLE I

Class of emission	Modulating signal	Condition of no-modulation	Conversion factor	
			Carrier power/ Peak envelope power	Mean power/ Peak envelope power
(1)	(2)	(3)	(4)	(5)
Amplitude-modulation *Double-sideband* A1 Telegraphy without modulation by a periodic oscillation	Series of rectangular dots; equal alternating marks and spaces; zero mark amplitude (Note 1)	Continuous emission	1	0·500 (−3·0 dB) (Note 1)
F2 Telegraphy with on-off keying of carrier frequency-modulated by a low-frequency periodic oscillation	Series of rectangular dots; equal alternating marks and spaces; single sinusoidal oscillation modulating the main carrier; no emission during space periods (Note 1)	Continuous emission	1	0·500 (−3·0 dB) (Note 1)
A2 Telegraphy with on-off keying of one or more low-frequency periodic oscillations amplitude - modulating the carrier, or with keying of the carrier modulated by those oscillations (see Table II)	Series of rectangular dots; equal alternating marks and spaces; single sinusoidal oscillation modulating the carrier at 100%			
	(a) modulating oscillation keyed	Continuous emission, modulating oscillation suppressed (carrier only)	0·250 (−6·0 dB)	0·312 (−5·1 dB)
	(b) modulated carrier keyed (Note 1)	Continuous emission with modulating oscillation	0·250 (−6,0 dB)	0·187 (−7·3 dB) (Note 1)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/ Peak envelope power (4)	Conversion factor: Mean power/ Peak envelope power (5)
A2 Continuous signal of carrier amplitude-modulated by low-frequency periodic oscillation (Example: some radio beacons)	Single sinusoidal oscillation modulating the carrier to 100%; no keying	Continuous emission, modulating oscillation suppressed (carrier only)	0·250 (−6·0 dB)	0·375 (−4·3 dB)
A3 Double-sideband telephony, full carrier (see Table II)	*(a)* single sinusoidal oscillation modulating the carrier at 100%	Carrier only	0·250 (−6·0 dB)	0·375 (−4.3 dB)
	(b) smoothly read text (Note 2)	Carrier only	0·250 (−6·0 dB)	0·262 (−5·8 dB)
Amplitude-modulation Single-sideband A2H Continuous signal of carrier amplitude-modulated by periodic oscillation, full carrier	Single sinusoidal oscillation modulating the carrier at 100%; no keying	Modulating oscillation suppressed (carrier only)	0·250 (−6·0 dB)	0·500 (−3·0 dB)
A3A Single-sideband telephony, reduced carrier	*(a)* two sinusoidal oscillations modulating transmitter to peak envelope power	Reduced carrier only	0·025 (−16.0 dB) 0·0025 (−26·0 dB)	0·379 (−4·2 dB) 0·454 (−3·4 dB)
	(b) smoothly read text (Note 2)	Reduced carrier only	0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·096 (−10·2 dB) 0·093 (−10·3 dB)
A3H Single-sideband telephony, full carrier	*(a)* single sinusoidal oscillation modulating carrier at 100%	Carrier only	0·250 (−6·0 dB)	0·500 (−3·0 dB)
	(b) smoothly read text (Note 2)	Carrier only	0·250 (−6·0 dB)	0·275 (−5·6 dB)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/ Peak envelope power (4)	Conversion factor: Mean power/ Peak envelope power (5)
A3J Single-sideband telephony, suppressed carrier	*(a)* two sinusoidal oscillations modulating transmitter to peak envelope power	Suppressed carrier	<0·0001 (<−40 dB)	0·500 (−3·0 dB)
	(b) smoothly read text (Note 2)	Suppressed carrier	<0·0001 (<−40 dB)	0·100 (−10 dB)
Amplitude-modulation Independent-sideband A3B Two independent telephony sidebands, carrier reduced or suppressed	*(a)* single sinusoidal oscillation on each sideband, modulating the transmitter to peak envelope power, both bands being modulated to the same level	Reduced carrier only	0·025 (−16 dB) 0·0025 (−26 dB)	0·379 (−4·2 dB) 0·454 (−3·4 dB)
		Suppressed carrier	<0·0001 (<−40 dB)	0·500 (−3·0 dB)
	(b) smoothly read text on each of two sidebands simultaneously (one channel per sideband (Notes 2 and 3)	Reduced carrier only	0·025 (−16 dB) 0·0025 (−26 dB)	0·061 (−12·1 dB) 0·048 (−13·2 dB)
		Suppressed carrier	<0·0001 (<−40 dB)	0·050 (−13 dB)
	(c) smoothly read text on each of the four channels simultaneously (two per sideband) (Notes 2 and 3)	Reduced carrier only	0·025 (−16 dB) 0·0025 (−26 dB)	0·096 (−10·2 dB) 0·093 (−10·4 dB)
		Suppressed carrier	<0.0001 (<−40 dB)	0·100 (−10 dB)
Amplitude-modulation Facsimile A4 Facsimile : direct modulation of the main carrier by the picture signal	Black and white chequerboard picture giving square wave; modulating the carrier as for A1	Continuous emission	1	0·500 (−3·0 dB)
A4 Facsimile : sub-carrier frequency-modulated by the picture signal, and amplitude-modulating the main carrier	Any picture, 100% amplitude-modulation of main carrier (the conversion factors are independent of the form of the picture signal)	Main carrier only	0·250 (−6·0 dB)	0·375 (−4·3 dB)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/Peak envelope power (4)	Conversion factor: Mean power/Peak envelope power (5)
A4A Facsimile : sub-carrier frequency-modulated by the picture signal and amplitude-modulating the main carrier, single-sideband, reduced carrier	For this class of emission, the modulating by the picture signal alters the power distribution within the occupied bandwidth without affecting the total power	Reduced carrier only	0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·733 (−1·3 dB) 0·905 (−0·4 dB)
A4J Facsimile : sub-carrier frequency-modulated by the picture signal and amplitude-modulating the main carrier, single-sideband, suppressed carrier	For this class of emission, the modulation by the picture signal alters the power distribution within the occupied bandwidth without affecting the total power	Suppressed carrier	<0·0001 (<−40 dB)	1
Amplitude-modulation Television A5C Television, vestigial sideband, picture only	*(a) All white* – 405 lines, 50 fields, positive modulation – 525 lines, 60 fields, negative modulation – 625 lines, 50 fields, negative modulation – 819 lines, 50 fields, positive modulation	(Note 4)		0·800 (−1·0 dB) 0·164 (−7·9 dB) 0·177 (−7·5 dB) 0·742 (−1·3 dB)
	(b) All black – 405 lines, 50 fields, positive modulation – 525 lines, 60 fields, negative modulation – 625 lines, 50 fields, negative modulation – 819 lines, 50 fields, positive modulation	(Note 4)		0·080 (−11·0 dB) 0·608 (−2·2 dB) 0·542 (−2·7 dB) 0·085 (−10·7 dB)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/ Peak envelope power (4)	Conversion factor: Mean power/ Peak envelope power (5)
Multichannel Telegraphy A7A and A7B (Note 5) Multichannel voice-frequency telegraphy. Single - or independent - sideband, reduced carrier	Frequency-shift or 2-tone voice-frequency channel telegraphy	Reduced carrier only		
	2 channels		0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·379 (−4·2 dB) 0·454 (−3·4 dB)
	3 channels		0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·261 (−5·8 dB) 0·302 (−5·2 dB)
	4 or more channels (Note 6)		0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·202 (−6·9 dB) 0·228 (−6·4 dB)
A7J Multichannel voice-frequency telegraphy, single-sideband, suppressed carrier	Frequency-shift or 2-tone voice-frequency channel telegraphy	Suppressed carrier		
	2 channels		<0·0001 (<−40 dB)	0·500 (−3·0 dB)
	3 channels		<0·0001 (<−40 dB)	0·333 (−4·8 dB)
	4 or more channels (Note 6)		<0·0001 (<−40 dB)	0·250 (−6·0 dB)
A9B (Note 5) Combination of speech and multichannel teelgraphy. Independent - sideband, reduced or suppressed carrier	Smoothly read text on one channel and one group of multichannel telegraph signals; 4 or more channels (Notes 6 and 7)	Reduced carrier only	0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·132 (−8·8 dB) 0·138 (−8·6 dB)
		Suppressed carrier	<0·0001 (<−40 dB)	0·151 (−8·2 dB)
	Smoothly read text on two channels and one group of multichannel telegraph signals; 4 or more channels (Notes 6 and 7)	Reduced carrier only	0·025 (−16·0 dB) 0·0025 (−26·0 dB)	0·105 (−9·8 dB) 0·105 (−9·8 dB)
		Suppressed carrier	<0·0001 (<−40 dB)	0·113 (−9·5 dB)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/ Peak envelope power (4)	Conversion factor: Mean power/ Peak envelope power (5)
Frequency or phase modulation				
F1	For these classes of emission the modulation changes the distribution of power in the frequency spectrum while leaving the total power unchanged	Various	1	1
F2 (frequency displacement on modulating oscillation)			1	1
F3			1	1
F4			1	1
F5			1	1
F6			1	1
F9			1	1
Pulse modulation				
P0 Continuous emission of a series of periodic pulses for radiodetermination. (See Note 8 for definition of *d*)	Periodic series of identical non-modulated pulses: amplitude, width (duration), repetition frequency of pulses are constant	Without change	*d*	*d*
Telegraphy with on-off keying of a periodic oscillation which modulates a series of periodic pulses. (See Note 8 for the definition of *d*)	Series of rectangular dots; equal alternating marks and spaces; a single sinusoidal oscillation modulating the pulses			
P2D Periodic oscillation modulating the amplitude of the pulses	Amplitude of pulses modulated by sinusoidal oscillation at 100%			
	(a) modulating oscillation keyed	Continuous periodic series of pulses, modulating oscillation suppressed	0·250*d* (−6·0+ 10 log *d*) dB	0·312*d* (−5·1+ 10 log *d*) dB
	(b) modulated emission keyed (Note 1)	Continuous series of pulses with modulating oscillation	0·250*d* (−6·0+ 10 log *d*) dB	0·187*d* (−7.3+ 10 log *d*) dB (Note 1)

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Carrier power/ Peak envelope power (4)	Conversion factor: Mean power/ Peak envelope power (5)
P2E Periodic oscillation modulating the width (duration) of pulses to constant mean width (duration)	*(a)* modulating oscillation keyed	Continuous periodic series of pulses with modulating oscillation suppressed	*d*	*d*
	(b) modulated emission keyed (Note 1)	Continous series of pulses with modulating oscillation	*d*	0·500*d* (−3·0+ 10 log *d*) dB (Note 1)
P2F Periodic oscillation modulating the phase or position of the pulses to constant mean spacing	*(a)* modulating oscillation keyed	Continuous periodic series of pulses with modulating oscillation suppressed	*d*	*d*
	(b) modulated emission keyed	Continuous series of pulses with modulating oscillation	*d*	0·500*d* (−3·0+ 10 log *d*) dB
Pulse modulation Telephony P3D Pulses amplitude-modulated by telephone signal	*(a)* single sinusoidal oscillation modulating pulses at 100%	Periodic series of non-modulated pulses	0·250*d* (−6·0+ 10 log *d*) dB	0·375*d* (−4·3+ 10 log *d*) dB
	(b) smoothly read text (Note 2)	Periodic series of non-modulated pulses	0·250*d* (−6·0+ 10 log *d*) dB	0·262*d* (−5·8+ 10 log *d*) dB
P3E Pulses width (duration)—modulated to constant mean width (duration) by telephone signal	The mean width (or duration) and spacing being constant, the conversion factors are independent of the modulating signal	Periodic series of non-modulated pulses	*d*	*d*
P3F Pulses phase (or position) — modulated to constant mean spacing by telephone signal	The mean width (or duration) and spacing being constant, the conversion factors are independent of the modulating signal	Periodic series of non-modulated pulses	*d*	*d*

2.2 *Conversion factors with respect to the carrier power*

2.2.1 Table II gives the conversion factors applicable when the carrier power is taken as the unit, as is the common practice at least for the two classes of amplitude-modulated emissions A2 and A3.

2.2.2 Column 5 gives the theoretical mean power obtained with the modulating signals described in Column 2, with practically linear transmitters. The conversion factors shown are the quotients of the corresponding factors in Columns 5 and 4 of Table I.

2.2.3 Similarly, Column 4 gives the theoretical peak envelope power. The conversion factors shown are the reciprocals of the corresponding factors in Column 4 of Table I.

2.2.4 Column 3 gives the conditions of no-modulation from which the carrier power chosen as the unit can be determined and measured.

TABLE II

Class of emission (1)	Modulating signal (2)	Condition of no-modulation (3)	Conversion factor: Peak envelope power/ Carrier power (4)	Conversion factor: Mean power/ Carrier power (5)
A2 Telegraphy with on-off keying of one or more periodic oscillations amplitude-modulating the carrier, or with keying of the carrier modulated by those oscillations	Series of rectangular dots; equal alternating marks and spaces; single sinusoidal oscillation modulating the carrier at 100%			
	(a) modulating oscillation keyed	Continuous emission, modulating oscillation suppressed (carrier only)	4 (+6·0 dB)	1.25 (+1·0 dB)
	(b) modulated carrier keyed (Note 1)	Continuous emission with modulating oscillation	4 (+6·0 dB)	0.75 (−1·3 dB) (Note 1)
A3 Double-sideband telephony, full carrier	*(a)* single sinusoidal oscillation modulating carrier at 100%	Carrier only	4 (+6·0 dB)	1·5 (+1·8 dB)
	(b) smoothly read text (Note 2)	Carrier only	4 (+6·0 dB)	1.05 (+0·2 dB)

2.3 *Explanatory notes*

Note 2.3.1 – When the modulating signal, instead of consisting of a series of alternating marks and spaces, is coded with the help of a telegraph alphabet, the conversion factors in Column 5 should be multiplied by the following coefficients:

Morse alphabet: 0·49/0·50 = 0·98 (—0·1 dB)

International telegraph alphabet No. 2: 0·58/0·50 = 1·16 (+0·6 dB)

Seven-unit alphabet as in Recommendation 342-1: 0·5/0·5 = 1.

Note 2.3.2 – It is assumed that for smoothly read text the mean power level of the speech signal is 10 dB lower than the power level of a reference sinusoidal oscillation. The conversion factors in Column 5 are based on this ratio which can be considered as a practical value for telephony except for sound transmissions in the broadcasting service.

For the classes of emission to which this note applies, the reference level of this sinusoidal oscillation is determined as follows:

- A3, A3H and P3D emissions: the level of a sinusoidal oscillation which would modulate the transmitter to a modulation factor of 100%;
- single-channel A3A and A3J emissions: the level of a sinusoidal oscillation which would modulate the transmitter to its peak envelope power;
- multi-channel A3A, A3B and A3J emissions: the level of a sinusoidal oscillation which would modulate the transmitter to one quarter (—6 dB) of its peak envelope power.

Although these assumptions do not in all cases correspond to the practice adopted by some Administrations, they result in practical average values in Column 5.

Note 2.3.3 – For independent-sideband emissions (A3B), of 3 or 4 channels, it is assumed that independent modulating signals are applied to each channel.

Note 2.3.4 – The condition of no-modulation cannot be defined exactly because of the highly complex and asymmetric nature of the modulation; the figures given in Column 5 are average figures which may vary according to the tolerance in width of the synchronizing pulses and of the black level. Detailed characteristics of the television systems are given in Report 308-1.

Note 2.3.5 – The power relationships in multi-channel voice-frequency telegraphy depend on the number of channels and not on the bandwidth they occupy. Therefore, either one or both sidebands can be occupied, and there is no distinction to be made here between A7A and A7B emissions.

Telegraph signals can occupy all the channels of an emission as in A7A and A7B telegraphy, or can occupy one or more channels of a composite (A9B) emission. It is therefore convenient to regard the group of voice-frequency telegraph channels as equivalent to one or more normal speech channels.

Note 2.3.6 – The ratios given in Table I are based on the conditions mentioned below which are considered typical of present practice.

- When one to four telegraph channels are used, the mean power of each channel is determined on the basis of voltage addition. Thus, if n is the number of channels of identical level, the mean power of each channel is given by:

$$\frac{\textit{Peak envelope power allocated to the group of channels}}{n^2}, \text{ when } n = 1, 2, 3 \text{ or } 4.$$

- When more than four telegraph channels are used it is normal practice to increase the level of each channel above that for which the peak envelope power allocated to the group of channels would never be exceeded. Since it may be assumed that the phases of the different sub-carriers are randomly distributed, the mean power of the emission may thus be increased without this peak envelope power being exceeded for more than a specified small fraction of the time.

  In this case, the mean power of each channel is given by:

$$\frac{\textit{Peak envelope power allocated to the group of channels}}{4n}, \text{ when } n > 4.$$

Under this condition, the peak envelope power allocated to the group of channels is not exceeded for more than about 1% to 2% of the time.

Note 2.3.7 – For composite emissions, the mean levels in speech channels are assumed to be adjusted to the values set out in Note 2.3.2 for A3B emissions. To avoid interference from the group of telegraph channels, the level of this group is assumed to be reduced, relative to the level as set out in Note 2.3.6, by 3 dB when one channel is used for speech and by 6 dB when more than one channel is used.

Note 2.3.8 – For pulse emissions, it is assumed that the pulses are rectangular and that the peak envelope power is unity. The duty cycle d is the ratio of pulse duration to pulse repetition period, and is a constant for amplitude-modulated pulses. Where the duty cycle is variable. as with position or width modulated pulses, d is to be taken as the average value.

3. Determination and measurement of the power of a radio transmitter

that the determination and measurement of the power of a radio transmitter should be made on the basis of the following considerations and methods:

3.1 *Peak envelope power and intermodulation distortion of amplitude-modulated transmitters for single-channel and multi-channel telephony either double-sideband, single-sideband or independent-sideband, and for multi-channel voice-frequency telegraphy.*

3.1.1 *General considerations*

For amplitude-modulated transmitters, it is not always possible to measure directly the peak envelope power. For an ideal, perfectly linear transmitter this can be calculated theoretically from measurement of the mean power or of the carrier power of the emission, but the difference between the actual peak envelope power and the value thus calculated depends primarily on the degree of non-linearity of an actual transmitter.

Moreover, the coincidence of the measurements of the ratio of the mean power to the carrier power with the theoretical values is not a sure criterion of the linearity of the transmitter because of the distortion which may, as a function of the input level, increase the mean power linearly without proportionally increasing the peak envelope power.

The peak envelope power of a perfectly linear, double-sideband transmitter with full carrier (A2, A3 or A4), modulated at 100%, would be four times greater than the carrier power. But all transmitters are to some extent non-linear, and this defect produces signal distortion and also an increase in out-of-band radiation. To keep these undesirable effects to the minimum, it is necessary to limit the peak envelope power to a useful value which, for a double-sideband transmitter with full carrier, is equivalent to limiting the modulation depth to less than 100%.

The peak envelope power is limited by the acceptable intermodulation distortion. The method recommended for defining and measuring the peak envelope power of a single-sideband or independent-sideband transmitter (A3A, A3B, etc. emissions) is described below. The same method may also be used for double-sideband transmitters (A3 emission).

3.1.2 *Intermodulation*

3.1.2.1 *Principle for the measurement of intermodulation distortion*

The imperfect linearity of amplitude-modulated radio transmitters can be expressed as a function of the level of the intermodulation products. To determine that level, it is convenient to measure separately the amplitude of each intermodulation oscillation resulting from the application, at the input of the transmitter, of two periodic modulating sinusoidal oscillations with frequencies f_1 and f_2.

As a rule, the amplitudes of the two modulating oscillations are adjusted in such a way that they produce, at the output of the transmitter, fundamental components of equal amplitude at the radio frequencies $F_0 + f_1$ and $F_0 + f_2$ (or $F_0 - f_1$ and $F_0 - f_2$).

Only the intermodulation products corresponding to integral coefficients whose difference is unity ($p - q = 1$), fall within the necessary band or near enough to it and have an appreciable amplitude. The intermodulation products of the third order ($p + q = 3$) generally have the greatest amplitude, but for certain transmitters higher orders—for example of the fifth order ($p + q = 5$), may also show appreciable amplitudes. To limit these intermodulation products, which may cause excessive out-of-band radiation, a level, valid for all orders of intermodulation products, should be fixed.

3.1.2.2 *Choice of frequencies for modulating oscillations*

To measure the amplitude of the intermodulation products, it is desirable to use modulating oscillations having frequencies near the limits of the audio-frequency passband. The audio-frequency passband to be considered here is the band at the input of the transmitter which corresponds at the output, to the whole of a sideband of an emission.

Harmonics and intermodulation components, mainly of even order, may originate in the low-frequency equipment at the input of the transmitter or during the processes of modulation. To prevent these coinciding or interfering at the output of the transmitter with the intermodulation components of the third and the fifth order to be measured, the modulating frequencies f_1 and f_2 should be chosen carefully.

A harmonic relation between the modulating frequencies f_1 and f_2 should be avoided, as well as a ratio f_1/f_2 having a value in the neighbourhood of $^2/_3$, $^2/_5$, $^2/_7$, $^3/_4$, $^3/_5$, $^3/_7$ and $^4/_5$. With respect to the latter condition it is assumed that for most practical purposes intermodulation components of orders higher than the fifth may be neglected.

In an audio-frequency passband between 300 Hz and 3 kHz, for example, a value in the neighbourhood of 700 or 1100 Hz may be chosen for f_1, and in the neighbourhood of 1700 Hz or 2500 Hz for f_2, in which case the requirements stated above are satisfied.

3.1.2.3 *Acceptable intermodulation level*

The intermodulation level considered here is expressed in terms of the ratio, generally in decibels, between the powers of the largest intermodulation component at radio frequency, $p\,(F_o \pm f_1) - q\,(F_o \pm f_2)$ and the power of the fundamental component at radio frequency ($F_o \pm f_1$ or $F_o \pm f_2$) produced by one of the two f_1 and f_2 modulating oscillations applied singly at the input of the transmitter, the amplitudes of which are adjusted as indicated above (§ 3.1.2.1, 2nd paragraph).

The intermodulation level that can be regarded as acceptable depends on the class of emission and the service for which the transmitter is intended. From this aspect, three main categories of emissions can be considered:

First category

- Single-sideband single-channel radiotelephone emissions (A3A, A3J, A3H) without a privacy device.

For these classes of emission, the major part of the energy of the modulating signal is concentrated in the part of the spectrum containing relatively low audio frequencies. If, after modulation, the high power components remain near to the carrier in frequency, fairly high levels of intermodulation can be tolerated without serious increase in out-of-band radiation or noticeable distortion.

The acceptable intermodulation level can be taken as —25 dB or less.

If an emission of the same class is used with a privacy device which may transpose the high power components to any position in the necessary band, the preceding condition is not met, and the emission must be transferred to the second category.

Second category

- Independent-sideband radiotelephone emissions (A3B)
- Multi-channel VF telegraph emissions (A7A and A7B)
- Independent-sideband multiplex emissions (A9B)
- Single-sideband or double-sideband single-channel radiotelephone emissions (A3, A3A, A3J, A3H) with a privacy device.

For these classes of emission, intermodulation products cause interference between channels or undesirable out-of-band radiation. Their level must be more strictly limited.

The acceptable intermodulation level may be taken as —35 dB or less.

Third category

Double-sideband amplitude-modulated emissions.

The peak envelope power of double-sideband transmitters may also be measured by means of the method recommended in § 3.1.3. This is mainly of use in determining the out-of-band radiation characteristics fo the transmitter.

Some Administrations prefer to use the harmonic distortion method of measurement using a single sinusoidal modulating oscillation. For acceptable performance the modulation depth does not normally exceed 90%.

3.1.3 *Methods for measuring the peak envelope power*

It results from the foregoing that, because of non-linearity in the transmitters, the measurement of the peak envelope power must take into consideration the accepted intermodulation level for the transmitter in question, and that different measuring methods may give results which do not agree.

Hence it is desirable to adopt a single measuring method which is as simple and certain as possible.

The following method is recommended:

3.1.3.1 *Single- or independent-sideband amplitude-modulated transmitters with reduced or suppressed carrier*

(a) A voltage-calibrated oscilloscope is coupled to the antenna feed or to the transmitter load, so as to display the output voltage, with its envelope curve.

(b) The carrier of the transmitter is suppressed.

(c) The transmitter is modulated by a single sinusoidal oscillation so as to obtain a mean output power of about half the peak envelope power.
Measurements are made of the mean power by a calorimetric method or by a wattmeter previously calibrated by this method.
The peak voltage obtained on the oscilloscope is measured.

(d) The single modulating oscillation is replaced by two sinusoidal oscillations whose frequencies are chosen as indicated in § 3.1.2.2. The amplitudes of those two oscillations are adjusted so that the power of the largest

intermodulation component measured with appropriate equipment, with a filter if necessary, reaches the acceptable intermodulation level (as defined in § 3.1.2.3) and that simultaneously the two oscillations produce fundamental components of equal amplitude at the output of the transmitter (§ 3.1.2.1).

The peak voltage corresponding to the maximum of the envelope obtained on the oscilloscope is again measured.

(e) The peak envelope power is given by the formula:

$$\text{peak envelope power} = \text{mean power} \left[\frac{\text{peak voltage obtained with two oscillations}}{\text{peak voltage obtained with one oscillation}} \right]^2$$

3.1.3.2 *Single-sideband or double-sideband amplitude-modulated transmitters with full carrier*

A measuring method similar to that described in § 3.1.3.1 can be used.

- The carrier of the transmitter is not suppressed.
- The modulation used in § *(c)* above is suppressed.
- The mean reference power mentioned in § *(c)* is replaced by the carrier power and the corresponding peak voltage replaced by the carrier amplitude.
- The rest of the measurements proceeding as before, the peak envelope power is given by the formula:

$$\text{peak envelope power} = \text{carrier power} \left[\frac{\text{peak voltage obtained with two oscillations}}{\text{carrier amplitude}} \right]^2$$

RECOMMENDATION 327-1

MEASUREMENT OF SPECTRA AND BANDWIDTHS OF EMISSIONS

(1951 – 1953 – 1959 – 1963 – 1966)

The C.C.I.R.,

CONSIDERING

(a) that it is important to measure accurately the bandwidth occupied by an emission and to determine its spectrum;

(b) that some tentative figures can be offered for the degree of accuracy to be attained in the measurement of bandwidth and spectra;

(c) that a practical basis must be furnished for the determination of the necessary bandwidth for a service of suitable grade;

UNANIMOUSLY RECOMMENDS

that attention should be paid to the following:

1. Method of measurement of bandwidth

Three main methods are at present in use:

1.1 *Method with single band-pass filter*

The first method consists in analyzing completely the spectrum of the emission by means of a narrow-band filter of fixed frequency, the frequency of each component being made to coincide with the central frequency of the filter by a change in frequency, controlled either manually or automatically.

1.2 *Methods with high-pass filters*

The second method consists in comparing the total power of the emission and the power remaining after filtering by a high-pass filter, the cut-off frequency of which can be shifted at will, with respect to the emission spectrum, by means of variable frequency change. Two variants of this method have been described.

1.2.1 *Single-filter method*

With this method, use is made of a single fixed high-pass filter. By means of the variable-frequency oscillator of the frequency changer, two cut-off frequencies are determined such that, above the first frequency and below the second, the powers at the output of the filter are 0·5% of the total power of the emission at the input. The bandwidth is given by the difference between these two cut-off frequencies.

The measuring procedure can be simplified by using an adjustable oscillator, working alternately at two frequencies of constant mean value, their difference being adjusted by a single control and read directly on the corresponding dial (Doc. I/12 (Japan), Geneva, 1962).

If the spectral distribution is not too asymmetrical, a simpler method can be used, in which the frequency components of the rectified signal are selected by means of a high-pass filter, the cut-off frequency of which is progressively increased (Doc. 128 (Japan), London, 1953).

1.2.2 *Two-filter method* (Doc. I/40 (P. R. of Poland), Geneva, 1958).

With this method, use is made of two identical fixed high-pass filters for the independent selection of the upper and lower out-of-band components of the signal; two frequency-converters are used, the oscillators of which are automatically and independently adjusted, so that each of the two filters selects the pre-determined proportion of the power.

1.3 *Method with multiple band-pass filters* (Docs. 79 (U.S.A.) and 274 (Austria), London, 1953).

The third method consists in dividing the occupied band into narrow bands of, say, 100 Hz, for each of which a pass-band filter is provided; the output of each of these filters is connected either individually and permanently to a measuring device, or successively and automatically to a single measuring device. This method seems especially suitable for the examination of non-periodic signals, such as radiotelephone emissions.

1.4 *Method applicable in the presence of noise or interference*

When one is far enough from the transmitter for noise and interference from emissions in adjacent radio channels to reach an appreciable level, it may become impossible to determine directly, without significant error, the frequencies beyond which only a small fraction of the power radiated by the emission to be measured exists (such as the fraction of 0·5% corresponding to the definition of occupied bandwidth).

Approximate methods of making such measurements are described in Report 324.

2. Accuracies required for bandwidth measurement

2.1 *Periodic signals of Class A1*

2.1.1 *Apparatus using the method described in § 1.1*

2.1.1.1 *Laboratory apparatus.* This apparatus requires that the signals under test shall give rise to a spectrum, the components of which should be stable in amplitude and in frequency. Amplitudes are measured by means of a calibrated attenuator with reference to a constant level; frequencies are measured by means of a frequency meter.

If the stability conditions referred to above are satisfied, the accuracy of the measurement depends only on the accuracy of calibration of the attenuator and of the frequency meter.

An accuracy of ±1% in the measurement of the amplitude is obtainable, but an accuracy of ±5% is sufficient for most practical purposes.

2.1.1.2 *Automatic sweep apparatus*

Provided the speed for frequency scanning is sufficiently slow to take full advantage of the high selectivity of the filter, and that this selectivity is sufficient to eliminate the effect of high-level components on the measurement of low-level components, the amplitudes of the components can be measured with an accuracy of ±2 dB.

The accuracy of measurement of frequency deviations depends mainly on the linearity of the sweep and on the width of the explored band. Nevertheless, with periodic signals, the frequency intervals between successive components are generally known by the modulation rate.

2.1.2 *Apparatus using the method described in § 1.2*

The accuracy of this measuring equipment depends on the sensitivity of the measurement of power ratio, and on the steepness of the attenuation curve of the high-pass filter.

The sensitivity of the measurement of power ratio should be of the order of ±0·1 %, but the errors due to the attenuation characteristics of the filters will of course depend on the type of filter employed.

2.1.3 *Apparatus using the method described in § 1.3*

When the component frequencies of the signal correspond approximately to the mid-band frequencies of the filters, accuracies of ±1 % should be obtained.

2.2 *Periodic signals of Class F1*

2.2.1 *Apparatus using the method described in § 1.1*

If it is possible to form periodic-F1 signals, for which there are corresponding components stable in amplitude and in frequency, the same accuracies can be achieved as those mentioned in §§ 2.1.1.1 and 2.1.1.2 for periodic signals of type A1. It is pointed out, however, that in the present case, the components which can be measured with an accuracy of ±2 dB with automatic sweep apparatus, are those adjacent to the mark and space frequencies.

2.2.2 *Apparatus using the method described in § 1.2* (see § 2.1.2)

2.2.3 *Apparatus using the method described in § 1.3* (see § 2.1.3)

2.3 *Actual traffic signals*

For a variety of reasons that can be fairly easily demonstrated theoretically, it is usually difficult to carry out spectrum measurements on emissions carrying actual traffic, particularly with band-pass filter analyzers. The results are not generally stable, unless complex indicators with a very long integration time are used; in addition, they are not mutually consistent, especially with analyzers having different characteristics. Nor are they consistent with the results of measurements carried out with periodic signals, and there do not seem to be any fairly simple correction formulae to enable consistency to be attained in practice.

Some results of measurements, carried out on A1 and F1 emissions, with actual telegraph traffic, using analyzing filters with a bandwidth equal, or slightly higher, than the modulation rate, seem to be fairly consistent with the results of measurements carried out with periodic signals (see Doc. 1/7 (Federal Republic of Germany), Geneva, 1962). However, with such bandwidths, not only the details of the spectrum disappear, but the general shape of the energy spectrum appears to be flattened, compared to that measured with a narrow filter. The measured spectrum is, therefore, rather different from the theoretical spectrum, which would be approached with a filter much narrower than the modulation rate.

ANNEX I

Characteristics of measuring equipment with automatic frequency-sweep

Equipment suitable for analyzing the spectrum of transmitters operating in the medium and high frequency ranges usually possess the following characteristcs:

1. Filter bandwidth

The filter bandwidth depends essentially on the characteristics of the signal to be studied. It should be small in comparison with the width of the spectrum to be measured, and whilst, at the present, it is inappropriate to specify a single value of bandwidth to the exclusion of others, it is desirable that the steady-state bandwidth of the filter should not exceed 25 Hz. Its attenuation-frequency characteristics should be steep-sided down to about 60 dB.

2. Scanning speed

Although fairly high scanning speeds might prove useful for preliminary adjustments, when it is desirable to take full advantage of the resolving power of the filter for fine analysis, the scanning speed must be sufficiently slow for the response curve of the filter to be as near as possible to the steady-state selectivity curve. The admissible value of the scanning speed depends essentially on the filter characteristics and should be determined experimentally in each case.

It can be said that the permissible scanning speed, expressed in hertz per second, should not exceed the square of the filter bandwidth at the —3 dB points, expressed in hertz.

3. Scanning range

The scanning range shall be adequate to include the outermost significant sideband components likely to be encountered. A maximum total sweep of 30 kHz should normally be adequate. For investigating narrow-band emissions, the range should be adjustable down to 1 kHz.

4. Suppression of automatic sweep

Provision should be made for stopping the automatic sweep to enable manual scanning to be used in certain cases.

5. Form of display

For direct observation, the display may take the form of a cathode-ray tube, but other means such as recording meters may be used.

6. Amplitude range

The range of amplitude displayed should be such that it is possible to measure components differing in amplitude by at least 60 dB. The amplitude scale of the display instrument may be linear or logarithmic. It may be desirable to measure separately and by stages the major and minor components such as may be obtained by the use of a calibrated attenuator or a calibrated scale applied to the oscilloscope screen.

7. Frequency stability

The frequency stability of the various beating oscillators must be such that the drift during the course of a measurement is small compared with the effective resolving power of the filter.

ANNEX II

Principal characteristics of the frequency-spectrum analysers presented before the C.C.I.R. VIIIth Plenary Assembly

Origin	Doc. No.	Exploration			Filter				Amplitude range (dB)	Measuring instrument		Measurement of the component frequency
		Type	Sweep duration	Frequency band explored (kHz)	Type	Bandwidth		Frequency (kHz)		Observations	Recording	
						at —3 dB	at other level					
Japan	127	automatic	1 min 5 min	6 and 20	crystal		50 Hz at —25 dB	55	60	voltmeter	record on paper	
Netherlands	136	automatic	20 s 2 min 6·7 min	1; 5; 25	Selective feed back amplifier	Adjustable between 8 and 40 Hz		40	0-20 20-40 40-60	oscillo-scope	recorder	
United Kingdom	168 (1)	automatic	0·1; 0·3; 1; 3; 10; 30 s	0 to 30	crystal	6 Hz 3 Hz 150 Hz		60	0-30 30-60	oscillo-scope	photo-graphic	
Switzerland	191	automatic and manual	0·1 to 60 s	20; 60 in 3 steps	electro-mechn.		80 Hz at —43·5 dB	3		oscilloscope or peak voltmeter	photo-graphic	marks each 1 kHz
Italcable	199	manual			LF		50 Hz at —80 dB	1	calibrated attenuator	voltmeter		frequency-meter
France	349	automatic	6 and 36 s	2 and 6	crystal		6 or 30 Hz below —80 dB	70	60	oscillo-scope	photo-graphic	
Belgium	(2)	automatic	6; 20; 45 s	0·5 to 30	crystal	9 Hz		195	20 dB linear scale 60 dB loga-rithmic scale	oscillo-scope	photo-graphic	marks 0·5 or 1 kHz

(1) This apparatus has been demonstrated before Study Group I.
(2) This apparatus has been demonstrated before Study Group I, but was not described in a C.C.I.R. document.

RECOMMENDATION 328-1

SPECTRA AND BANDWIDTHS OF EMISSIONS

(1948 – 1951 – 1953 – 1956 – 1959 – 1963 – 1966)

The C.C.I.R.,

CONSIDERING

(a) that it is of the utmost importance to ensure economy of the radio spectrum by reducing the spacing between assigned frequencies;

(b) that, to this end, it is necessary to reduce, as much as possible, the bandwidth occupied by each emission, in accordance with Article 12, § 5 and Article 14, § 4 of the Radio Regulations, Geneva, 1959; that moreover Appendix 5 to the Radio Regulations is provided as a guide for the determination of the necessary bandwidth;

(c) that, for the determination of a spectrum of minimum width, the whole transmission circuit as well as all its technical working conditions, and particularly, propagation phenomena, must be taken into account;

(d) that one cannot, strictly speaking, mention bandwidth without having previously adopted quantitative definitions of the various bandwidths by fixing well determined points on the complete spectrum;

(e) that the definitions of " occupied bandwidth " and " necessary bandwidth " given in Article 1, Nos. 90 and 91, of the Radio Regulations, Geneva, 1959, are useful to specify the spectral properties of a given emission, or class of emission, in the simplest possible manner;

(f) that, however, these definitions do not suffice when consideration of the complete problem of radio spectrum economy is involved; and that an endeavour should be made to establish rules limiting, on the one hand, the bandwidth occupied by an emission to the value strictly necessary in each case and, on the other hand, the amplitudes of the components emitted in the outer parts of the spectrum, so as to decrease interference to adjacent channels;

(g) that the three concepts:

- necessary bandwidth;
- occupied bandwidth;
- spectrum emitted outside the necessary bandwidth;

should be applied according to the following principles:

(g.a) the necessary bandwidth should be established at the smallest value possible, while including the spectrum components useful to a good receiver to ensure communication with the quality required by the two correspondents (for example, maintaining the telephone quality laid down, or the error rate admitted in telegraphy), under given technical conditions;

(g.b) the occupied bandwidth enables operating agencies, and national and international organizations to carry out measurements of the bandwidth actually occupied by a given emission and thus to ascertain, by comparison with the necessary bandwidth, that such an emission does not occupy an excessive bandwidth for the service to be provided and is, therefore, not likely to create harmful interference beyond the limits laid down for this class of emission. The use of this concept appears to be a useful way of ensuring that operating agencies restrict the emitted energy outside the necessary bandwidth;

(g.c) the emitted spectrum outside the necessary bandwidth must be determined by reconciling the following requirements:

- the necessity for limiting the interference caused to adjacent channels to a strict minimum;
- the technical and practical possibilities of transmitter design;
- the limitation of shaping or distortion of the signal to a permissible value;

(h) that, although some problems of spacing between channels or even interference can be dealt with in an approximate but simple manner, merely by use of the data for the necessary bandwidth (for a given class of emission), or occupied bandwidth (for a given emission), or for the spectrum emitted outside the necessary bandwidth; interference problems can be dealt with accurately only if complete knowledge is available, either of the Fourier transform of the signal, or of the function representing its energy spectrum for all frequencies in the radio-frequency spectrum;

UNANIMOUSLY RECOMMENDS

1. Definitions

1.0 that the following definitions and explanatory notes should be used when dealing with bandwidth, channel spacing and interference problems:

1.1 *Occupied bandwidth* (Article 1, No. 90 of the Radio Regulations, Geneva, 1959)

" The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0·5 % of the total mean power radiated by a given emission. In some cases, for example multichannel frequency-division systems, the percentage of 0·5 % may lead to certain difficulties in the practical application of the definitions of occupied and necessary bandwidth; in such cases a different percentage may prove useful.'

1.2 *Necessary bandwidth* (Article 1, No. 91 of the Radio Regulations, Geneva, 1959)

" For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth."

1.3 *Out-of-band spectrum* (of an emission)

The part of the energy spectrum of an emission which is oustide the necessary band, with the exception of spurious radiations at frequencies remote from the limits of the necessary bandwidth, such as harmonics, certain intermodulation products, etc.

Note. – Spurious radiations at frequencies remote from the limits of the necessary band are not included in out-of-band radiation, since they should be covered by separate rules from those governing out-of-band radiation.

1.4 *Out-of-band radiation* (of an emission)

The total power radiated at the frequencies of the out-of-band spectrum.

Note. – The bandwidth occupied by a given emission, considered perfect from the point of view of spectrum economy, coincides with the necessary bandwidth for the corresponding class of emission. In this case, the out-of-band radiation is equal to 1 % of the total mean radiated power. If the occupied bandwidth is greater than the necessary bandwidth, this percentage is higher.

1.5 *Frequency band occupied* (by an emission)

The frequency band in the radio spectrum such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0·5 % of the total mean power radiated by the emission.

1.6 *Assigned frequency band* (Article 1, No. 89 of the Radio Regulations, Geneva, 1959)

"The frequency band, the centre of which coincides with the frequency assigned to the station and the width of which equals the necessary bandwidth plus twice the absolute value of the frequency tolerance."

1.7 *Build-up time of a telegraph signal*

The time during which the telegraph current passes from one-tenth to nine-tenths (or vice versa) of the value reached in the steady state; for asymmetric signals, the build-up times at the beginning and end of a signal can be different.

2. Limitations of the emitted spectra

2.0 that, since some present emissions (particularly class A1 emissions), occupy an unduly wide bandwidth, Administrations should endeavour, with the minimum practicable delay, to limit the emitted spectra to those shown below for various classes of emission.

Note. – The modulation rate in bauds, *B*, used in the following text is the maximum speed used by the corresponding transmitter. For a transmitter operating at a speed lower than this maximum speed, the build-up time should be increased to keep the occupied bandwidth at a minimum, to comply with Article 12, § 5, No. 674, of the Radio Regulations, Geneva, 1959.

2.1 *Class of emissions A1 with fluctuations*

2.1.0 When large short-period variations of the received field are present, the specifications given below for single-channel, amplitude-modulated, continuous-wave telegraphy (class A1), represent the desirable performance obtainable from a transmitter with an adequate input filter and sufficiently linear amplifiers following the stage in which keying occurs.

2.1.1 *Necessary bandwidth*

The necessary bandwidth is equal to five times the modulation rate in bauds. Components at the edges of the band are attenuated by at least 3 dB relative to the levels of the same components of a spectrum representing a series of equal rectangular dots and spaces at the same modulation rate.

This relative level of −3 dB corresponds to an absolute level of 27 dB below the mean radiated power of the continuous emission.*

2.1.2 *Out-of-band spectrum*

The curve representing the out-of-band spectrum should lie below a curve starting at the point ($\pm 5B/2$, −27 dB) defined above, with a slope of 30 dB per octave, extending over at least one octave out to the points ($\pm 5B$, −57 dB). Beyond these points, the level of all components emitted should be below −57 dB.

2.1.3 *Build-up time of the signal*

The build-up time of the emitted signal depends essentially on the shape of the signal at the input to the transmitter, on the exact structure of the filters to which this signal is applied, and on filtering and non-linear effects which may take place in the transmitter itself (assuming that the antenna has no influence on the shape of the signal). As a first approximation, it can be accepted, that a spectrum curve close to the limiting spectrum defined in §§ 2.1.1 and 2.1.2, corresponds to a build-up time of about 20% of the initial duration of the telegraph dot, i.e. of the order of $1/(5B)$.

* See Recommendation 326-1, Table I.

2.2 *Class of emission A1, without fluctuations*

For amplitude-modulated, continuous-wave telegraphy, when short-period variations of the received field strength do not affect transmission quality, the necessary bandwidth can be reduced to three times the modulation rate in bauds.

2.3 *Class of emission A2*

2.3.0 For single-channel telegraphy, in which both the carrier frequency and the modulating oscillations are keyed, the percentage of modulation not exceeding 100% and the modulation frequency being higher than the modulation rate ($f > B$), the specifications given below represent the desirable performance that can be obtained from a transmitter with a fairly simple input filter and approximately linear stages.

2.3.1 *Spectrum*

Outside a bandwidth equal to twice the modulating frequency f plus five times the modulation rate in bauds, the envelope of the spectrum should lie below a curve starting at the points [$\pm(f+5B/2)$, −24 dB] with a slope of 12 dB per octave, and extending over at least one octave, that is, out to the points [$\pm(f+5B)$, −36 dB]. Beyond these points the level of all the components emitted should be below −36 dB.

The reference level corresponds to that of the carrier in a continuous emission with modulating oscillation.

2.4 *Amplitude-modulated radiotelephone emission*

The spectrum limits described in this section for radio-telephone emissions have been deduced from various measurements. The peak envelope power of the transmitter is first determined using the method described in Recommendation 326-1, § 3.1.3, and the transmitter is adjusted for an acceptable distortion for the class of service.

Measurements have been made using several different modulating signals substituted for the two audio tones. It has been found that white noise, with the bandwidth limited by filtering to the desired bandwidth of the information to be transmitted in normal service, is a satisfactory substitute for a speech signal in making practical measurements.

In the curves defined in §§ 2.4.1 and 2.4.2 the ordinates represent the energy intercepted by a receiver of 3 kHz bandwidth the central frequency of which is tuned to the frequency plotted on the abscissa, normalized to the energy which is intercepted by the same receiver when tuned to the central frequency of the occupied band.

However, a receiver with 3 kHz bandwidth cannot provide detailed information in the frequency region close to the edge of the occupied band. It has been found that point-by-point measurements with a receiver having an effective bandwidth of 100 to 250 Hz or with a spectrum analyzer with similar filter bandwidth is more useful in analyzing the fine structure of the spectrum.

To make these measurements the attenuation-frequency characteristics of the filter limiting the transmitted bandwidth should first be determined. The transmitter is then supplied with a source of white noise limited to a bandwidth somewhat larger than the transmitted bandwidth. Care should be exercised to insure that the peaks of the noise signal at the input do not exceed the level corresponding to the peak envelope power of the transmitter for percentages of time larger than approximately 0·5%. The actual value of this time percentage can be evaluated in terms of the mean noise power-to-peak envelope power and of the bandwidth of the white noise, assuming that the noise follows a gaussian distribution. Results of recent measurements using the foregoing narrow-band techniques and a white noise signal to modulate the transmitter are given in Report 325.

2.4.1 *Class of emission A3, double-sideband*

2.4.1.1 *Necessary bandwidth*

The necessary bandwidth F is, in practice, equal to twice the highest modulation frequency, M, which it is desired to transmit with a specified small attenuation.

2.4.1.2 *Power within the necessary band*

The statistical distribution of power within the necessary band is determined by the relative power level of the different speech frequency components applied at the input to the transmitter or, when more than one telephony channel is used, by the number of active channels and the relative power level of the speech frequency components, applied at the input to each channel.

When no privacy equipment is connected to the transmitter, it should be assumed that the power distribution in the relevant band of speech frequencies at each channel corresponds to the relative response curve given in C.C.I.T.T. Recommendation G.227 (see Annex II). This curve is not applicable to broadcast service. Some information concerning the curve that might be used in this case is contained in Report 399.

If the transmitter is used in connection with a frequency inversion privacy equipment, the same data can be used with appropriate frequency inversion of the resulting spectrum.

If a band-splitting privacy equipment is used, it should be assumed that the statistical distribution of power is uniform within the frequency band.

2.4.1.3 *Out-of-band spectrum*

If frequency is plotted as the abscissa in logarithmic units and if the power densities are plotted as ordinates, in decibels, the curve representing the out-of-band spectrum should lie below two straight lines starting at point ($+0{\cdot}5F$, 0 dB) or at point ($-0{\cdot}5F$, 0 dB), and finishing at point ($+0{\cdot}7F$, 20 dB) or ($-0{\cdot}7F$, -20 dB), respectively. Beyond these points and down to the level of -60 dB, this curve should lie below two straight lines starting from the latter points and having a slope of 12 dB per octave. Thereafter, the same curve should lie below the level -60 dB.

The reference level corresponds to the power density that would exist, if the total power, excluding the power of the carrier, were distributed uniformly over the necessary bandwidth.

2.4.2 *Single-sideband, classes of emission A3A, A3H and A3J (reduced, full or suppressed carrier) and independent-sideband, class of emission A3B*

2.4.2.1 *Necessary bandwidth*

2.4.2.1.1 For classes of *emission* A3A and A3H, the necessary bandwidth F is, in practice, equal to the value of the highest audio frequency, f_2, which it is desired to transmit with a specified small attenuation.

2.4.2.1.2 For class of emission A3J, the necessary bandwidth F is, in practice, equal to the difference between the highest f_2 and lowest f_1 of the audio frequencies which it is desired to transmit with a specified small attenuation.

2.4.2.1.3 For class of emission A3B, the necessary bandwidth F is, in practice, equal to the difference between the two radio frequencies most remote from the assigned frequency, which correspond to the two extreme audio frequencies to be transmitted with a specified small attenuation in the two outer channels of the emission.

2.4.2.2 *Power within the necessary band*

For considerations with regard to the power in the necessary band, reference is made to § 2.4.1.2.

2.4.2.3 *Out-of-band spectrum for class of emission A3B; four telephony channels simultaneously active.*

The out-of-band radiation is dependent on the number and position of the active channels. The curves described below are only appropriate when four telephone channels are active simultaneously. When some channels are idle, the out-of-band radiation is less.

If frequency is plotted as the abscissa in logarithmic units, the reference frequency being supposed to coincide with the centre of the necessary band, and if the power densities are plotted as ordinates, in decibels, the curve representing the out-of-band spectrum should lie below two straight lines starting at point ($+0{\cdot}5F$, 0 dB), or at point ($-0{\cdot}5F$, 0 dB), and finishing at point ($+0{\cdot}7F$, -30 dB) or ($-0{\cdot}7F$, -30 dB), respectively. Beyond the latter points and down to the level -60 dB, this curve should lie below two straight lines starting from the latter points and having a slope of 12 dB per octave. Thereafter, the same curve should lie below the level -60 dB.

The reference level corresponds to the power density that would exist if the total power, excluding the power of the reduced carrier, were distributed uniformly over the necessary bandwidth.

2.5 *Class of emission F1*

For class of emission F1, frequency-shift telegraphy, with or without fluctuations due to propagation:

2.5.1 *Necessary bandwidth*

If the frequency shift, or the difference between mark and space frequencies is $2D$ and if m is the modulation index, $2D/B$, the necessary bandwidth is given by one of the following formulae, the choice depending on the value of m:

$2{\cdot}6\,D + 0{\cdot}55\,B$ within 10% for $1{\cdot}5 < m < 5{\cdot}5$,
$2{\cdot}1\,D + 1{\cdot}9\,B$ within 2% for $5{\cdot}5 \leqslant m \leqslant 20$.

2.5.2 *Out-of-band spectrum*

The curve representing the out-of-band spectrum should lie below a curve of constant slope in decibels per octave, starting from points situated at the frequencies limiting the necessary bandwidth, and extending to -60 dB. The levels are indicated relative to a zero level corresponding to the mean power of the emission. The starting ordinates of the curve and its slope are given in the following Table, as functions of the modulation index m:

Modulation index	Starting ordinates (dB)	Slope (dB per octave)
$1{\cdot}5 \leqslant m < 6$	-15	$13+1{\cdot}8\,m$
$6 \leqslant m < 8$	-18	$19+0{\cdot}8\,m$
$8 \leqslant m < 20$	-20	$19+0{\cdot}8\,m$

At frequencies more remote from the central frequency than those where the curve reaches the level -60 dB, the level of all emitted components should lie below -60 dB.

2.5.3 *Build-up time of the signal*

A spectral curve, close to the limiting spectrum described in §§2.5.1 and 2.5.2, corresponds to a build-up time equal to about 8% of the duration of the initial telegraph dot, i.e. about $1/(12B)$, provided that an adequate filter is used for signal shaping.

2.5.4 *Bandwidth occupied, for unshaped signals*

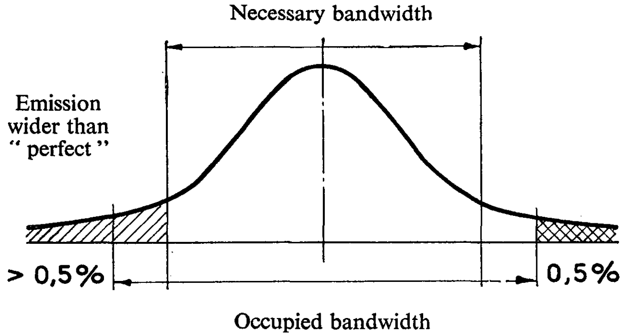
For the purpose of comparison with the above formulae, it may be mentioned that, for a sequence of equal and rectangular (zero build-up time) mark and space signals, the occupied bandwidth is given by the following formulae:

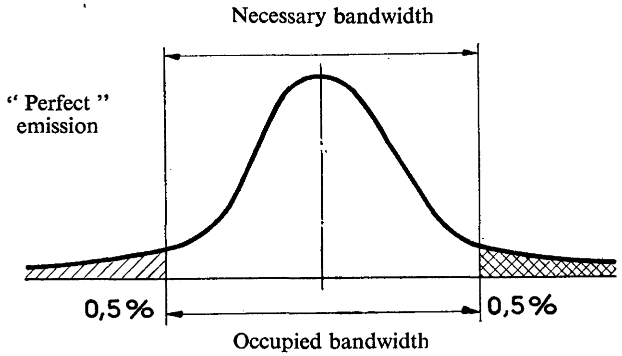
$2{\cdot}6\,D + 1{\cdot}4\,B$ within 2% for $2 \leqslant m \leqslant 8$,
$2{\cdot}2\,D + 3{\cdot}1\,B$ within 2% for $8 \leqslant m \leqslant 20$.

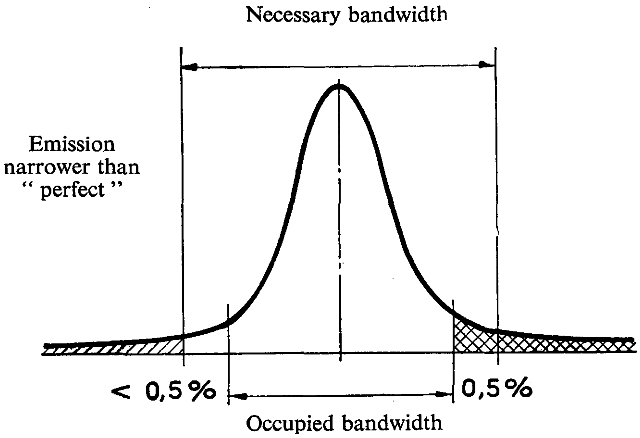
ANNEX I

Examples of spectra illustrating the definition of necessary bandwidth

Abscissae: frequencies
Ordinates: power per unit frequency
The spectra are assumed to be symmetrical

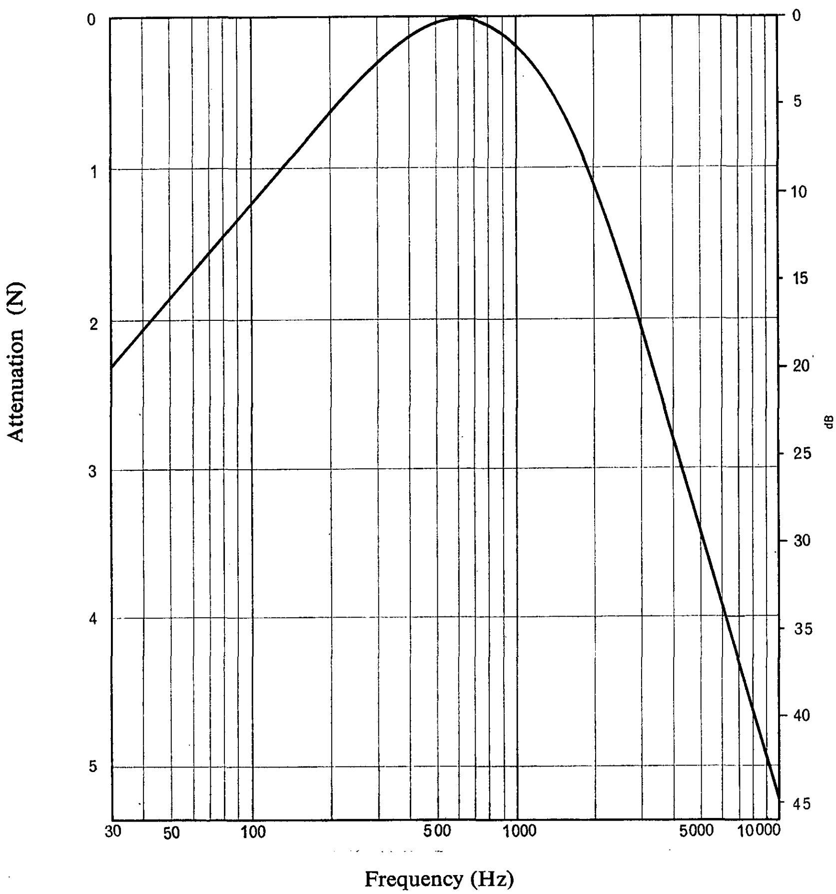






The hatched areas represent the out-of-band radiation (see definition § 1.3)
The cross-hatched areas represent radiation outside the occupied band (see definition § 1.1)

ANNEX II



Relative response curve of the weighting network of the conventional telephone signal generator

RECOMMENDATION 329-1

SPURIOUS RADIATION (OF A RADIO EMISSION)

(Study Programme 7A/I)

(1951 – 1953 – 1956 – 1959 – 1963 – 1966)

The C.C.I.R.,

CONSIDERING

(a) that Appendix 4 to the Radio Regulations, Geneva, 1959, specifies the maximum level of spurious emissions for all transmitters with fundamental frequencies below 235 MHz in terms of power supplied to the antenna transmission line at the frequency, or frequencies, of each spurious emission;

(b) that Article 12 (Nos. 672 and 673), of the Radio Regulations, Geneva, 1959, stipulates that stations must conform to the tolerances specified in Appendix 4 for spurious emissions; that, moreover, every effort should be made to keep spurious emissions at the lowest values which the state of the technique and the nature of the service permit;

(c) that measurements of power, at frequencies other than the fundamental frequencies supplied to a transmitting antenna or to a test load, are useful in the analysis of transmitter performance as regards purity of emissions under specific conditions, and that such measurements will encourage the use of certain means of reducing spurious emissions;

(d) that the relation between the power of the spurious emission supplied to a transmitting antenna and the field-strength of the corresponding signals, at locations away from the transmitter, may differ greatly, due to such factors as the horizontal and vertical antenna directivity at the unwanted radiation frequencies, propagation over various paths and radiation from parts of the transmitting apparatus other than the antenna itself;

(e) that field-strength measurements of spurious emissions, at locations distant from the transmitter, are recognized as the direct means of expressing the intensities of interfering signals due to such radiations;

(f) that, in dealing with emissions on the fundamental frequencies, Administrations customarily establish the power supplied to the antenna transmission line, and measure the field strength at a distance, to aid in determining when an emission is causing interference with another authorized emission; that a similar procedure would be helpful in dealing with spurious emissions (see Article 14, No. 697, of the Radio Regulations, Geneva, 1959);

(g) that for the most economic use of the frequency spectrum, it is necessary to lay down general maximum limits of spurious emissions, while recognizing that specific services may need lower limits for technical and operational reasons;

UNANIMOUSLY RECOMMENDS

1. Terminology and definition

that the following terms and definitions should be used to designate radiations that are regarded as spurious:

1.1 *Spurious radiation (of a radio emission)*

radiation at a frequency, or frequencies, outside the necessary band, the level of which may be reduced without affecting the corresponding transmission of information; spurious radiation includes harmonic radiation, parasitic radiation and unwanted intermodulation products which are remote from the necessary band;

1.2 *Harmonic radiation (of a radio emission)*

spurious radiation at frequencies which are whole multiples of those contained in the frequency band occupied by an emission;

1.3 *Parasitic radiation (of a radio emission)*

spurious radiation, accidentally generated, at frequencies which are independent both of the carrier or characteristic frequencies of an emission, and of frequencies of oscillations appearing in the course of generation of the oscillations at carrier or characteristic frequencies;

1.4 *Unwanted intermodulation products (of a radio emission or emissions)*

spurious radiation, at frequencies resulting from intermodulation between the oscillations at the carrier, characteristic or harmonic frequencies of an emission, or the oscillations which appear when these carrier or characteristic oscillations are produced, and oscillations of the same nature, of the same or several other emissions, originating from the same or different transmitting systems; spurious radiation, at frequencies or the harmonics of frequencies, used during the production of oscillations at the carrier or characteristic frequencies of an emission, is also included in the unwanted intermodulation products.

2. Application of limits

2.1 that for the time being, limits for spurious radiation continue to be expressed in terms of the power supplied by the transmitter to the antenna feeder at the frequencies of the spurious radiation considered;

2.2 that spurious radiation from any part of the installation, other than the antenna system, i.e. the antenna and its feeder, shall not have an effect greater than would occur if this antenna system were supplied with the maximum permissible power at that spurious radiation frequency;

2.3 that, in the event that the standards of performance in § 3 below are adopted by an Administrative Radio Conference as revised limits for Appendix 4 to the Radio Regulations, Geneva, 1959, a period of at least 3 years from the coming into force of the revised Regulations might be necessary, to enable all Administrations to attain these limits for new transmitters;

2.4 that where a transmitting system comprises more than one transmitter, the application of the limits specified in § 3 should apply with all transmitters operating normally.

3. Limits for the power of spurious radiations (see Notes 1 and 2)

3.1 that the following limits are realizable on new transmitters with fundamental frequencies between 10 kHz and 30 000 kHz (from Radio Regulations, Geneva, 1959, Appendix 4, Table, Column B):

for any spurious radiation, the mean power supplied to the antenna transmission line should be at least 40 dB below the power of the fundamental emission, without exceeding the value of 50 mW (for exceptions see Notes 3, 4 and 5);

3.2 that the following limits are realizable with new transmitters having fundamental frequencies between 30 MHz and 235 MHz (see Radio Regulations, Geneva, 1959, Appendix 4, Table, Column B):

3.2.1 *Transmitters with output power greater than 25 W at the fundamental frequencies*

for any spurious radiation, the mean power supplied to the antenna transmission line should be at least 60 dB below the power of the fundamental emission, without exceeding the value of 1 mW (for exceptions see Note 6);

3.2.2 *Transmitters with output power less than 25 W at the fundamental frequencies*

for any spurious radiation, the mean power supplied to the antenna transmission line should be at least 40 dB below the power of the fundamental emission, without exceeding the value of 25 μW;

3.3 that the following limits are realizable for new transmitters with fundamental frequencies between 235 MHz and 960 MHz:

3.3.1 *Transmitters with output power greater than 25 W at the fundamental frequencies*

for any spurious radiation, the mean power supplied to the antenna transmission line should be at least 60 dB below the power of the fundamental emission, without exceeding the value of 20 mW (for exceptions see Notes 7, 8, 9 and 10);

3.3.2 *Transmitters with output power less than 25 W at the fundamental frequencies*

it is not yet possible to specify limits for all transmitters in this category, due to lack of sufficient data: for transmitters in the frequency band up to 470 MHz, the mean power of the spurious radiation supplied to the antenna transmission line should not exceed 25 μW;

3.4 that the limits adopted by the Administrative Radio Conference should also be shown in the Radio Regulations, in the form of a graph as indicated in Fig. 1.

Note 1. – It is recognized that specific services may need lower limits for technical and operational reasons.

Note 2. – These limits are not applicable to life-boats, survival craft, and aeronautical and maritime emergency (reserve) transmitters.

Note 3. – For transmitters having an output power greater than 50 kW which can operate on two or more frequencies, covering a frequency range approaching an octave or more, it may not always be practicable to achieve a suppression greater than 60 dB.

Note 4. – For some hand-portable equipment of power less than 5 W, it may not be practicable to achieve a suppression of 40 dB, in which case a suppression of 30 dB should apply.

Note 5. – A limit of 50 mW may not be practicable for mobile transmitters, in which case the spurious radiation should be at least 40 dB below the fundamental emission, without exceeding the value of 200 mW.

Note 6. – In some areas, where the interference problem is not serious, a limit of 10 mW may be sufficient.

Note 7. – Where several transmitters feed a common antenna or closely spaced antennae on adjacent frequencies, it may not always be possible to achieve this degree of attenuation for spurious radiation, the frequencies of which are close to the occupied band.

Note 8. – For radio-determination stations, until acceptable methods of measurement exist, the lowest practicable level of spurious radiation should be achieved.

Note 9. – For survival stations operating at a frequency of 243 MHz, the lowest level of spurious radiation, consistent with the type of apparatus, should be achieved.

Note 10. – Since the limits mentioned above may not provide adequate protection for receiving stations in the radioastronomy and space services, lower limits might be considered in each individual case in the light of the geographical position of the stations concerned.

4. Methods of measurement of spurious radiation by measurement of power supplied to the antenna *

that, together with other known methods of measuring the power of spurious radiation, either the substitution method, or a direct power measuring method should be used, when the transmitter is operated under normal conditions and when connected to its normal antenna or to a test load. When the measurements are performed with the transmitter connected to a test load, the power of the spurious oscillations supplied to the test load might differ considerably from the spurious radiation supplied to the antenna used for actual transmission.

4.1 *Substitution method*

in the substitution method, an auxiliary generator, the output power of which can be varied, is employed and its frequency is adjusted to be equal to the mean frequency of the spurious radiation in question. This auxiliary generator is used as follows:

The generator is substituted for the radio transmitter and is adjusted until it produces the same field at the mean frequency of the spurious radiation as was produced by the radio transmitter (in intensity and polarization). This field is measured by means of a radio receiver tuned to the spurious radiation and located at a distance of several wavelengths from the transmitting antenna. The power supplied by the generator is then equal to the power originally supplied by the transmitter itself, on condition that non-linearity of the radiating system does not introduce harmonic radiation. To obtain the same conditions with the generator, account must be taken of any stray coupling from the original transmitter to the radiating system and of any direct radiation from the transmitter and from feeder lines or other apparatus that may become excited by direct coupling. It is also necessary to take into account the possibility of the power of a spurious radiation being supplied in a push-pull or push-push mode or combination of both. More than one generator may be necessary when the method of excitation is complex. It is also necessary to determine the impedance of the feeder input circuit at the spurious frequencies, in order that the power supplied to the antenna may be measured accurately. It is necessary that several sets of measurements be made using different receiver locations.

When a test load is used, an indicator coupled to the load is required.

4.2 *Direct methods*

the following three direct methods of measurement can be used:

4.2.1 *First method.* (See Doc. 130, London, 1953.) The voltage, current and power factor are determined at one point on the feeder using a selective radio receiver tuned to the mean frequency of the spurious radiation concerned, and coupled to the desired point of the feeder.

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* Relevant documents are: Docs. 65, 80, 101, 124, 130 and 340, London, 1953; Doc. 313, Warsaw, 1956; Docs. I/22, I/28 and I/34, Geneva, 1958; Docs. I/1, I/17 and I/23, Geneva, 1962 and Doc. I/54, 1963-1966.

4.2.2 *Second method.* (See Doc. I/1, Geneva, 1962.) The forward and reflected powers are determined by using a pair of inverse directional couplers, inserted directly in the feeder line or the test load; a selective power-measuring device is switched alternatively to the couplers and tuned to the mean frequency of the spurious radiation concerned. The difference between these two measured powers gives the power supplied to the antenna at the frequencies of the spurious radiation.

For coaxial lines a directional coupler may consist of a conductor (linear antenna), arranged within the feeder, parallel to its axis, and provided at one of its ends with a reflectionless termination relative to the external conductor. A voltage appears at the open end that is due entirely to the voltage wave in the feeder, which extends from the open end of the linear antenna to the closed end. The dimensions and spacing between the conductors of the coupler and the external wall depend on the maximum permissible input level and on the input impedance of the measuring set to be connected.

The method enables the power of spurious radiation transferred from a transmitter to the antenna to be measured, regardless of whether it is generated directly in the transmitter concerned or in a secondary manner, e.g. by interaction with other transmitters.

For balanced feeder lines (see Doc. I/1, 1963-1966), a directional coupler may consist of a pair of parallel conductors (symmetrical linear antenna) arranged symmetrically near the feeder in a plane parallel to the plane containing the feeder. The directional coupler is provided with a reflectionless termination at one end.

A voltage, balanced relative to ground, appears at the open end due entirely to the push-pull mode of the wave on the feeder. For selective measurement of the voltage it is preferable to transform it from balance to unbalance by a transformer.

If the couplers are arranged as mentioned above, the push-push mode of the wave on the feeder has a negligible influence on the measurement. The extent of this influence depends on the balance of the transformer used.

The spacing between the coupler and the feeder and the distance between the two conductors of the coupler depend on the maximum permissible input level of the selective level meter to be connected and the transformation ratio of the transformer used.

When power components of substantial magnitude transferred in a push-push mode can be expected, these components should be measured separately by using another appropriate method.

Another measuring equipment suitable for balanced feeder lines (see Doc. I/40, 1963-1966) uses two coaxial feeder sections, each of which is fitted with two directional couplers. Thus the forward and reflected powers can be determined separately for each of the two conductors.

The sum of the forward powers is equal to the total power transferred to the transmission line. The method does not, however, distinguish between the power in the push-pull and push-push modes.

A special type of directional coupler can be used for measuring the power of spurious radiations over a wide range of frequencies.

4.2.3 *Third method.* (See Doc. I/23, 1962.) Measurement is made of electromotive force values at the points of a node and anti-node on a symmetrical open-wire feeder and these values are converted into power values of the spurious radiation at the frequency to be measured. The electromotive force values are measured by means of a coupling element and a selective radio receiver tuned to the mean frequency of the spurious radiation concerned. The coupling element is a screened loop placed symmetrically between the feeder conductors and moved at will along the feeder to locate the nodes and anti-nodes. By changing the position of the plane of the loop in relation to the plane of the feeder conductors, it is possible to measure the power of the push-pull and push-push modes of the spurious radiation.

The coefficient used for conversion of the measured values into power values is found from a graph plotted previously, at the time of calibration of the device.

4.3 *Measurements of spurious radiation at frequencies close to the fundamental frequencies.* (See Doc. I/17, 1962.)

4.3.1 In view of the difficulty of measuring spurious radiations which are relatively close to the necessary band, it may not be possible to ensure that the limitations set forth in § 3 are met in such cases (see Study Programme 7A/I, § 2).

4.3.2 In many cases, adequate suppression of oscillations which unduly disturb the measurement of spurious radiations on nearby frequencies can be effected by the insertion of suitable band-pass filters. Additional selective suppression of the carrier oscillation for instance when measuring spurious radiation on nearby frequencies, can be realized by cancelling the carrier in the monitoring receiver with an unmodulated carrier in antiphase, obtained from a low power stage (see Doc. I/55, 1963-1966.)

4.3.3 When several transmitters work on nearby frequencies in the same station, and may even be feeding the same antenna, as may happen, for instance, in sound broadcasting stations using frequency modulation at the frequencies in band 8, intermodulation products may be found with a frequency separation less than 1 MHz from the carrier frequencies in use.

In such cases, the methods of measurement described above may be somewhat difficult to apply. It may then be preferable to measure the field strength on the spurious frequency and on a nearby carrier frequency at a convenient distance (a few or a few tens of kilometres), with a sufficiently selective measuring instrument. The power of spurious radiation can then be calculated. When it is assumed that the wideband antenna has substantially identical input impedance and gain on these two frequencies, small errors are introduced which can be corrected if separate measurements are made of these impedances and of the gain in the direction of the field measuring instrument.

5. Further improvements

that Administrations and private operating agencies should continue to improve the degree of suppression of spurious radiation, where this is economically possible, to reduce interference to other services to a greater extent than that given in § 3. Guidance on the means of reducing the level of spurious radiation from transmitters is given in Report 326.

6. Radioastronomy

that radioastronomy, using extremely sensitive receivers, should probably be afforded with special protection; the C.C.I.R. is unable to proceed with the study of this problem until an answer to Question 10/IV has been provided;

7. Space service

that another special case requiring urgent study is to be found in the space services; it seems likely that earth stations will have very powerful transmitters, spurious radiations from which may cause considerable interference, and will have very sensitive receivers which may need special protection; at present, the C.C.I.R. lacks sufficient data for commencing a study of this problem, which, however, should be resolved as soon as possible, to prevent a difficult situation arising which it may be impossible to correct.

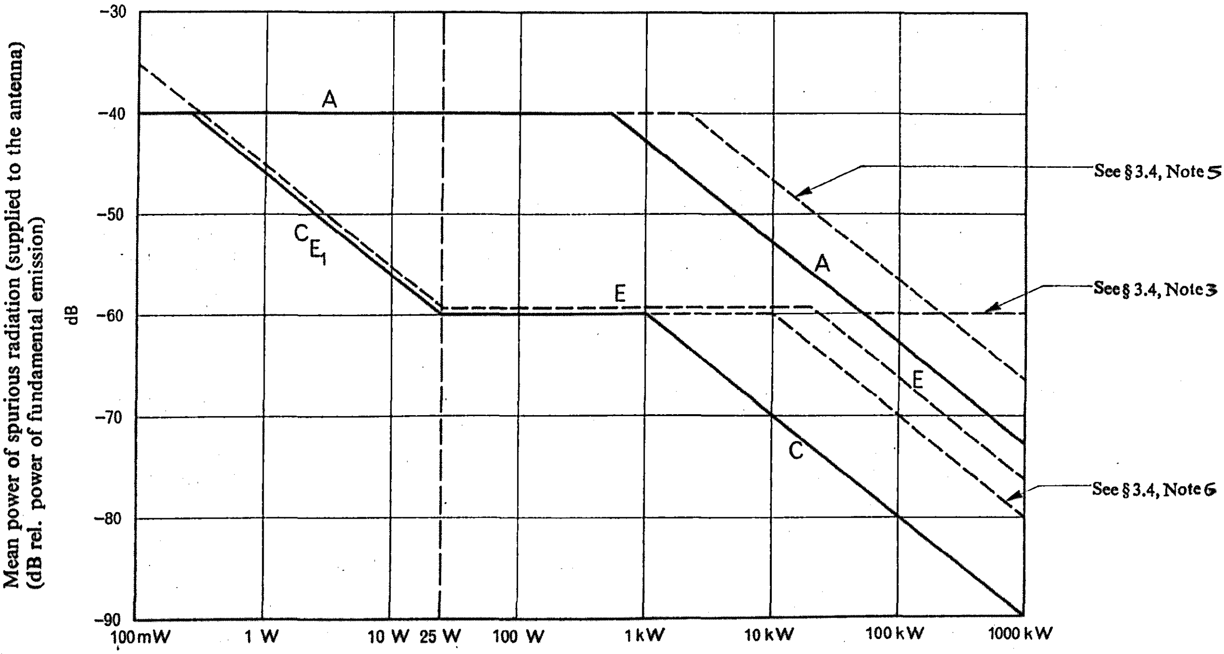

FIGURE 1

Curve A: 10 kHz < F < 30 MHz
Curve C: 30 MHz < F < 235 MHz
Curve E: 235 MHz < F < 960 MHz
Curve E_1: 235 MHz < F < 470 MHz
(F = fundamental frequency)

RECOMMENDATION 432 *

CLASSIFICATION AND DESIGNATION OF EMISSIONS

(Question 1/I)

(1966)

The C.C.I.R.,

CONSIDERING

(a) that Article 2, Section I, of the Radio Regulations, Geneva, 1959, classifies emissions for the purpose of designation;

(b) that certain symbols are used for classes of emission which are not precisely specified;

(c) that it may be necessary to specify new classes of emission in the future;

(d) that, in the recording processes used by the International Frequency Registration Board and by certain Administrations, particularly in mechanical recording processes, a simple and precise method of designation is required, using the smallest practicable number of symbols for each designation to provide all the essential information;

(e) that it may be useful to combine, in a single series of symbols, the information now classified as supplementary characteristics with that giving the type of modulation of the main carrier;

(f) that the International Frequency Registration Board, in certain cases, requires from Administrations additional significant information of a supplementary nature—e.g. carrier level and telegraph signal code information, which is not always provided for in the present system of designation;

(g) that the present system of designation does not enable all emissions to be specified adequately;

UNANIMOUSLY RECOMMENDS

1. that Administrations should, in so far as it is practicable, take steps to prepare for the use of the method of designating their emissions as described below, with a view to introducing it for international application in the future;

2. that, in cases where it is necessary to more completely describe an emission, Administrations may complement the symbolic designation described below with an additional designation based on the decimal classification plan given in Annex I.

DESIGNATION OF EMISSIONS **

1. Emissions are designated according to their necessary bandwidth and their classification.

Section I

NECESSARY BANDWIDTH

2. Whenever the full designation of an emission is necessary, the symbol for that emission, as given below, shall be preceded by three numerical digits as follows:

The first two digits are the first two significant figures of the necessary bandwidth expressed in hertz, the third is the power of 10 by which the first two figures must be multiplied to produce the necessary bandwidth expressed in hertz. For example, necessary bandwidths of 25 Hz, 400 Hz, 2·4 kHz, 36 kHz, 180 kHz, 6·25 MHz, 200 MHz and 5·6 GHz, are expressed by the respective bandwidth indicator 250, 401, 242, 363, 184, 625, 207 and 568.

* This Recommendation replaces Report 175.

** For certain terms used herein, see Annex II.

Section II

CLASSIFICATION

3. Emissions are classified and symbolized according to the following characteristics, exceptional modulation used only for station identification being ignored:

Characteristics of the main carrier and type of modulation of this carrier (See § 4)

Type of final modulation signal (See § 5)

Characteristics of the basic signal conveying the information (See § 6)

4. Characteristics of the main carrier and type of modulation of this carrier

4.1 *Pure periodic sinusoidal main carrier*

		Symbol
4.1.0	Amplitude modulation, full carrier, double-sideband	A
4.1.1	Amplitude modulation, reduced or suppressed carrier, double-sideband	D
4.1.2	Amplitude modulation, full carrier, single-sideband	H
4.1.3	Amplitude modulation, reduced carrier, single-sideband	E
4.1.4	Amplitude modulation, suppressed carrier, single-sideband	J

Note. – Single-sideband emissions with suppressed carrier modulated only by a single sub-carrier should be classified by considering the radio-frequency produced by the sub-carrier as the main carrier-frequency.

4.1.5	Amplitude-modulation, reduced or suppressed carrier, independent-sidebands	B
4.1.6	Amplitude-modulation, full carrier, vestigial-sideband	C
4.1.7	Frequency-modulation	F
4.1.8	Phase-modulation	G

Note. – Where phase-modulation is used as a preliminary to the production of an amplitude-modulated or of a frequency-modulated emission, the resulting type of modulation of the carrier should be considered respectively as amplitude-modulation or frequency-modulation.

4.2 *Pure periodic sinusoidal main carrier, pulse-modulation*

4.2.1	Unmodulated pulse trains	P
4.2.2	A pure periodic sinusoidal carrier, modulated in amplitude by a periodic sequence of pulses which are in turn modulated by the basic signal:	
	4.2.2.1 in amplitude	K
	4.2.2.2 in width or duration	L
	4.2.2.3 in phase or position	M
	4.2.2.4 in code	N
	4.2.2.5 or by other means	Q
4.2.3	A pure periodic sinusoidal carrier, modulated in frequency or phase by a periodic sequence of pulses which are in turn modulated by the basic signal:	
	4.2.3.1 in amplitude	R
	4.2.3.2 in width or duration	S
	4.2.3.3 in phase or position	T

	Symbol
4.2.3.4 in code modulation	U
4.2.3.5 or by other means	V

4.3 *Other periodic main carriers*

4.3.1 Periodic sinusoidal oscillation, modified by one or more audio frequency periodic sinusoidal oscillations, the whole being modulated in amplitude by the final modulating signal	W
4.4 Cases not otherwise covered	Y
4.5 No modulation	X

5. Type of final modulating signal

5.0 One or more unmodulated periodic sinusoidal oscillations or unmodulated pulse train	0
5.1 Quantized signal, such as a telegraph signal, directly modulating the main carrier	1
5.2 Quantized signals, such as telegraph signals, modulating one or more sub-carriers	2
5.3 Analogue signals, such as voice signals, including sound signals in a broadcasting service, directly modulating the main carrier or modulating one **or** more sub-carriers	3

Note. – Multi-channel emissions designed to provide channels suitable for telephony and mostly used for this purpose should be classified as telephony emissions even if a minority of channels is used for other types of signal.

5.4 One or more facsimile signals directly modulating the main carrier or modulating one or more periodic sinusoidal sub-carriers	4
5.5 Video signal for television, or video signal combined with the associated sound signal where one emission includes both, or one or more such video signals with or without the associated sound signals modulating sub-carriers	5
5.6 Cases not otherwise covered	8
5.7 Composite signals consisting of a combination of signals of different type	9

Note. – Multi-channel emissions designed to provide channels suitable for telephony and mostly used for this purpose should be classified as telephony emissions even if a minority of channels is used for other types of signal.

6. Characteristics of the basic signal conveying the information

6.1 *Telegraph signals*

6.1.0 A small number of significant conditions, usually two per channel with signal elements of pre-determined duration; for example, alphabetic telegraphy or data transmission:

6.1.0.1 aural reception	A
6.1.0.2 automatic reception without error-correction	B
6.1.0.3 automatic reception with error-correction	C

Note. – This symbol should be used only if more than half of the channels carried by a multi-channel emission are equipped for error correction.

		Symbol
6.1.2	A multiplex signal where each of the possible combinations of signal elements in different channels is represented by a different condition of the carrier or sub-carrier; for example, four frequency diplex, with or without error- correction	L

6.2 *Facsimile signals*

6.2.1	A small number of significant conditions, usually two per channel with signal elements of continuously variable duration; for example, two-condition facsimile	W
6.2.2	Continuously variable signal; for example, half-tone facsimile	K

6.3 *Telephone signals*

6.3.1	Monophonic sound signal for broadcasting	M
6.3.2	Stereophonic or multiplex sound signal for broadcasting	S
6.3.3	Telephone signal not for connection to public service network	
6.3.3.1	With privacy device	N
	Note. – This symbol should be used for multi-channel telephone emission if one half or more of the circuits are equipped with a privacy or similar device which significantly alters the usual form of the signal energy spectrum.	
6.3.3.2	Without privacy device	V
6.3.4	Telephone signal of commercial grade for connection to public service network	
6.3.4.1	With privacy device	P
	Note. – This symbol should be used for multi-channel telephone emission if one half or more of the circuits are equipped with a privacy or similar device which significantly alters the usual form of the signal energy spectrum.	
6.3.4.2	Without privacy device	Q

6.4 *Video signal for television*

6.4.1	Monochrome television	T
6.4.2	Colour television	U

6.5 *Other signals*

6.5.1	Telemetering signal	D
6.5.2	Telecommand signal	E
6.5.3	Radiodetermination signal	F
6.5.4	Analogue signal for data transmission	G

6.6	*Cases not otherwise covered*	Y
6.7	*Two or more of the foregoing modulating signals simultaneously or in a pre-established sequence.* An example is a standard-frequency emission with time signals, standard audio frequencies, voice announcements, etc.	Z
6.8	*Classification not possible.* To be used by monitoring stations and in cases of harmful interference reports when the basic signal has not been recognized	X

ANNEX I

DECIMAL CLASSIFICATION PLAN

0 **One or more unmodulated periodic sinusoidal oscillations or unmodulated pulse train**

01 *Navigational radiodetermination systems*

011 Azimuth systems
0111 Non-directional systems
0112 Radio-range systems
0113 Rotating radio systems
012 Rho – Theta – systems
0121 DME – systems
0122 Tacan – system
013 Hyperbolic-system
0131 Decca
01311 Decca-Standard
01312 Decca-Mark X
01313 Decca-Hi-Fix
0132 Loran
01321 Loran A
01322 Loran B
01323 Loran C
0133 Lorac
01331 Lorac A
01332 Lorac B
0134 Toran
01341 Toran A
01342 Toran B
etc.

02 *Navigational radiodetermination systems (Radar)*

021 GCA-radar
0211 Precision approach radar
0212 Search radar

03 *Radiolocation systems*

031 Telemetry systems
032 Weather radar

1 **Quantized signal, such as a telegraph signal, directly modulating the main carrier**

11 *Morse telegraphy systems (including DCC-code)*

111 Morse, manual
112 Morse, automatic
113 DCC-code

12 *Radioteleprinter, single channel*

121 5-unit codes
1211 U5 No. 1
1212 U5 No. 2

122 6-unit codes
1221 U6 teletypesetter
123 7-unit codes
1231 U7 TOM
1232 U7 TOR
124 8-unit codes
125 9-unit codes
126 10-unit codes (U10)
1261 U10 Bauer code
1262 U10 Autospec

13 *Hellschreiber*

14 *Radioteleprinter multi-channel systems, time-division multiplex*

141 Baudot or Baudot-Verdan
1411 2 channels
1412 4 channels
1413 6 channels
1414 8 channels
142 ARQ-systems
1421 2 channels
1422 4 channels
1423 6 channels
1424 8 channels

15 *Radioteleprinter multi-channel systems, variable frequency arrangement of significant conditions*

151 Systems without time-division multiplex
1511 4 significant conditions, 2 channels
15111 4 significant conditions, 2 channels code 1
15112 4 significant conditions, 2 channels code 2
1512 5 significant conditions, 2 channels
1513 8 significant conditions, 3 channels
152 Systems with time-division multiplex
1521 4 significant conditions, 4 channels
15211 4 significant conditions, 4 channels code 1
15212 4 significant conditions, 4 channels code 2
1522 5 significant conditions, 4 channels
1523 8 significant conditions, 6 channels

2 **Quantized signals, such as telegraph signals, directly modulating one or more sub-carriers**

21 *Navigational radiodetermination systems*

211 Azimuth systems
2111 Non-directional systems
2112 Radio-range systems
2113 Rotating radio systems

22 *Morse telegraphy systems (including DCC-code)*

221 Morse, manual
222 Morse, automatic
223 DCC-code

23 *Radioteleprinter (single channel)*

231 Coquelet
232 Picolo

24 *Radioteleprinter, multi-channel, frequency-division multiplex, amplitude-modulated sub-carriers*

241 Up to 3 channels
2411 Sub-carrier separation 120 Hz
2412 Sub-carrier separation 170 Hz
242 4 to 6 channels
2421 Sub-carrier separation 120 Hz
2422 Sub-carrier separation 170 Hz
242 7 to 9 channels
etc.

25 *Radioteleprinter, multi-channel, frequency-division multiplex, frequency-modulated sub-carriers*

251 Up to 3 channels
2511 Centre-frequency separation 120 Hz
25111 Frequency deviation ± 30 Hz
25112 Frequency deviation ± 35 Hz
25113 Frequency deviation ± 42·5 Hz
2512 Centre-frequency separation 170 Hz
25121 Frequency deviation ± 30 Hz
25122 Frequency deviation ± 35 Hz
25123 Frequency deviation ± 42·5 Hz
2513 Centre-frequency separation 240 Hz
25131 Frequency deviation ± 30 Hz
25132 Frequency deviation ± 35 Hz
25133 Frequency deviation ± 42·5 Hz
25134 Frequency deviation ± 60 Hz
25135 Frequency deviation ± 85 Hz
2514 Centre-frequency separation 340 Hz
25141 Frequency deviation ± 30 Hz
etc.
2515 Centre-frequency separation 480 Hz
25151 Frequency deviation ± 30 Hz
etc.
2516 Centre-frequency separation 680 Hz
25161 Frequency deviation ±30 Hz
etc.
2517 Centre-frequency separation 960 Hz
25171 Frequency deviation ± 30 Hz
25172 Frequency deviation ± 35 Hz
25173 Frequency deviation ± 42·5 Hz
25174 Frequency deviation ± 60 Hz
25175 Frequency deviation ± 85 Hz
25176 Frequency deviation ± 120 Hz
25177 Frequency deviation ± 150 Hz
25178 Frequency deviation ± 170 Hz
25179 Frequency deviation > ± 170 Hz

252 4 to 6 channels
2521 Centre-frequency separation 120 Hz
etc.
253 7 to 9 channels
2531 Centre-frequency separation 120 Hz
etc.

26 *Radioteleprinter, multi-channel, frequency- and time-division multiplex, amplitude-modulated sub-carriers*

261 Up to 6 channels
2611 Sub-carrier separation 120 Hz
2612 Sub-carrier separation 170 Hz
262 7 to 12 channels
2621 Sub-carrier separation 120 Hz
2622 Sub-carrier separation 170 Hz
263 13 to 18 channels
etc.

27 *Radioteleprinter multi-channel, frequency- and time-division multiplex, frequency-modulated sub-carriers*

271 Up to 6 channels
2711 Centre-frequency separation 120 Hz
27111 Frequency deviation $\pm$ 30 Hz
27112 Frequency deviation $\pm$ 35 Hz
27113 Frequency deviation $\pm$ 42·5 Hz
2712 Centre-frequency separation 170 Hz
27121 Frequency deviation $\pm$ 30 Hz
etc.
2713 Centre-frequency separation 240 Hz
etc.

3 **Analogue signals, such as voice signals, including sound signals in a broadcasting service, directly modulating the main carrier, or one or more sub-carriers**

31 *Single-channel, marginal commercial quality, not for connection to public service network*
32 *Single-channel, commercial quality, suitable for connection to public service network*
33 *Single-channel, broadcast quality*
34 *Two-channel, broadcast quality amplitude-modulated sub-carrier frequency modulating the main carrier for stereo transmission*
35 *Multi-channel, broadcast quality one or more frequency-modulated sub-carriers*
36 *Two or more channels, marginal commercial quality not for connection to public service network*
37 *Two or more channels, commercial quality suitable for connection to public service network*

4 **One or more fascimile signals, directly modulating the main carrier, or modulating one or more periodical sinusoidal sub-carriers**

41 *Two-condition facsimile*

411 Index of cooperation 264
4111 60 rpm
4112 90 rpm
4113 120 rpm

412	Index of cooperation 352
4121	60 rpm
4122	90 rpm
4123	120 rpm
413	Index of cooperation 528
4131	60 rpm
4132	90 rpm
4133	120 rpm
414	Index of cooperation 576
4141	60 rpm
4142	90 rpm
4143	120 rpm
415	Index of cooperation 704
4151	60 rpm
4152	90 rpm
4153	120 rpm
42	*Half-tone facsimile*
421	Index of cooperation 264
4211	60 rpm
4212	90 rpm
4213	120 rpm
422	Index of cooperation 352
etc.	(as 412 to 415)

5 **Video signal for television**

51 *Television (monochrome)*

511 405 lines
512 525 lines
513 625 lines
514 819 lines

52 *Television (colour)*

521 NTSC

522 SECAM

523 PAL

53 *Industrial television*

8 **Cases not otherwise covered**

9 **Composite signals consisting of a combination of signals of different type**

91 *Simultaneous transmission of telephony and telegraphy with frequency-division multiplex*

92 *Simultaneous transmission of telephony and telegraphy with frequency- and time-division multiplex*

93 *Simultaneous transmission of facsimile and telegraphy with frequency-division multiplex*

etc.

ANNEX II

THE MEANING OF CERTAIN TERMS USED IN THIS RECOMMENDATION

Basic signal

A signal as originally formed to represent a single sequence of information in analogue or quantized form.

Main carrier

The wave that may be combined with a modulating signal in the last modulation stage of a radio transmitter.

Final modulating signal

The modulating signal which is combined with the main carrier in the last modulation stage of a radio transmitter.

Sub-carrier

A carrier which is employed in an intermediate modulating process.

ANNEX III

COMPARATIVE TABLE WITH EXAMPLES OF DESIGNATIONS OF CLASSES OF EMISSION

Description	Symbol proposed (§§ 4, 5, 6)	Present symbol according to Article 2 of the Radio Regulations
1. *Radiodetermination systems, standard frequency emissions, etc.*		
1.1 Main carrier, unmodulated	X	A0
1.2 Main carrier, modulated by a periodic sinusoidal oscillation:		
– amplitude-modulated, full carrier, double-sideband	A0	A2
– amplitude-modulated, full carrier, single-sideband	H0	A2H
– amplitude-modulated, reduced carrier, single-sideband	E0	A2A
– amplitude-modulated, suppressed carrier, single-sideband (1)	X	A2J
– frequency-modulated	F0	F2
1.3 Pulse emission, with no energy emitted between pulses, unmodulated pulse train	P0	P0

(1) See Note under § 4.1.4.

Description	Symbol proposed (§§ 4, 5, 6)	Present symbol according to Article 2 of the Radio Regulations
2. *Quantized signals such as those employed in telegraphy, data transmission, etc. using as basic signal two-condition elements of pre-determined duration*		
2.1 On-off keying of the main carrier by the basic signal, without the use of any audio frequency sub-carrier		
– for aural reception	A1A	A1
– for automatic reception, without error-correction	A1B	A1
2.2 On-off keying of the main carrier by the basic signal. The carrier is modified in amplitude or in frequency by an audio-frequency oscillation		
– for aural reception	W1A	A2 or F2
– for automatic reception, without error-correction	W1B	A2 or F2
2.3 Frequency-shift keying of the main carrier by the basic signal with two significant conditions, without the use of any audio-frequency sub-carrier:		
– for automatic reception, without error-correction	F1B	F1
– for automatic reception, with error-correction	F1C	F1
2.4 Four-frequency diplex	F1L	F6
2.5 Telegraph systems using sub-carrier modulation:		
2.5.1 On-off keying by the basic signal of a single sub-carrier which modulates the main carrier:		
– by amplitude-modulation, with full carrier and double sideband automatic reception with error-correction	A2C	A2
– by amplitude-modulation, with full carrier and single sideband, automatic reception without error-correction	H2B	A2H
– by amplitude modulation with reduced carrier and single sideband, automatic reception without error correction	E2B	A2A
– by amplitude-modulation, with suppressed carrier and single sideband automatic reception without error-correction (1)	A1B	A2J
Note – If keying is for station identification only, the emission should be classified as if the sub-carrier were unmodulated (see § 3)		
2.5.2 Frequency-shift keying by the basic signal of a single sub-carrier which modulates the main carrier as follows:		
– by amplitude-modulation, with full carrier and double sideband for automatic reception without error-correction	A2B	—
– by amplitude-modulation, with suppressed carrier, and single sideband for automatic reception without error correction (1)	F1B	—

(1) See Note under § 4.1.4.

Description	Symbol proposed (§§ 4, 5, 6)	Present symbol according to Article 2 of the Radio Regulations
2.5.3 On-off or frequency-shift keying by the basic signal, of independent sub-carrier in frequency-division multiplex systems, which together amplitude-modulate the main carrier with the following characteristics:		
– by single-sideband, suppressed-carrier for automatic reception without error-correction	J2B	A7J
– by independent-sideband, reduced-carrier for automatic reception with error-correction on the majority of channels	B2C	A7B
3. *Telephony*		
3.1 Amplitude-modulation of the main carrier by the basic signal:		
3.1.1 with double-sideband and full carrier:		
– for connection to public network with privacy device	A3P	A3
– not for connection to public network, without privacy device	A3V	A3
3.1.2 single-sideband, full carrier		
– for connection to public network with privacy device	H3P	A3H
– not for connection to public network, without privacy device	H3V	A3H
3.1.3 single-sideband, suppressed carrier		
– for connection to public network, with privacy device	J3P	A3J
3.1.4 independent-sideband, reduced carrier, for connection to public network		
– two channels, without privacy device	B3Q	A3B
– four channels, three of which have privacy device . .	B3P	A3B
3.2 Frequency-modulation of the main carrier by the basic signal, not for connection to the public network, without privacy device	F3V	F3
3.3 Telephone system carrying numerous channels, a few of which are used for telegraph signals and the remainder are for connection to public telephone network without privacy device, modulating the main carrier in frequency	F3Q	F9
3.4 Telephone signals converted to quantized form, frequency shift modulating the main carrier, for connection to public service network, with privacy device	F1P	—
3.5 Main carrier amplitude-modulated by a pulse train: telephone signals for connection to the public network:		
– modulating the pulse train in amplitude with privacy device	K3P	P3D
– modulating the pulse train by a coded signal without privacy device	N3Q	P3G

Description	Symbol proposed (§§ 4, 5, 6)	Present symbol according to Article 2 of the Radio Regulations
3.6 Main carrier frequency-modulated by a pulse train; telephone signals for connection to the public network:		
– amplitude-modulating the pulse train with privacy device . .	R3P	—
– modulating the pulse train by a coded signal without privacy device	U3Q	—
4. *Sound broadcasting*		
4.1 Single channel monophonic sound signal for broadcasting or the monophonic sound signal of a broadcast television service which modulates the main carrier		
– in amplitude with full carrier and double sideband	A3M	A3
– in amplitude with full carrier and single sideband	H3M	A3H
– in frequency	F3M	F3
4.2 Stereophonic or multiplex sound signal for broadcasting which modulates the main carrier		
– in amplitude with full carrier and double sideband	A3S	A3
– in frequency	F3S	F3
5. *Two-condition facsimile, data transmission, etc. (using as modulating signal two-condition elements of continuously variable duration)*		
5.1 On-off keying of the main carrier by the basic signal, without the use of any audio frequency sub-carrier	A4W	A4
5.2 Frequency-shift keying by the basic signal of an audio-frequency sub-carrier which modulates the main carrier in amplitude with the following characteristics:		
– by double-sideband, with full carrier	A4W	A4
– by single-sideband, with suppressed carrier	F4W	A4J
– by independent-sidebands, with suppressed carrier, 2 channels	B4W	A4B
5.3 Frequency-shift keying of the main carrier by the modulating signal	F4W	F4
6. *Half-tone facsimile analogue data transmission, etc. (using a continuously variable modulating signal)*		
6.1 Frequency modulation by the basic signal of an audio frequency sub-carrier which modulates the main carrier in amplitude with the following characteristics:		
– by double-sideband, with full carrier	A4K	A4
– by single-sideband, with suppressed carrier	F4K	A4J
– by independent-sidebands, with suppressed carrier, 2 channels	B4K	A4B
6.2 Frequency-modulation of the main carrier by the basic signal .	F4K	F4

Description	Symbol proposed (§§ 4, 5, 6)	Present Symbol according to Article 2 of the Radio Regulations
7. *Television*		
7.1 Amplitude-modulation of the main carrier by the basic signal, with full carrier, vestigial-sideband:		
– monochrome television	C5T	A5C
– colour television	C5U	A5C
7.2 Frequency-modulation of the main carrier by the basic signal:		
– monochrome television	F5T	F5
– colour television	F5U	F5
8. *Composite emissions*		
8.1 Simultaneous modulation of the main carrier by two telephone channels and sub-carriers modulated by 12 telegraph channels; amplitude-modulation, reduced carrier, independent-sidebands	B9Z	A9B
8.2 Main carrier frequency-modulated with 300 telephone channels and two television channels	F9Z	F9
9. *Telemetry*		
Pulse-code modulation, modulating the main carrier in amplitude .	N1D	—
10. *Telecommand*		
Pulse-position modulation, modulating the main carrier in frequency	T1E	—

RECOMMENDATION 433

METHODS FOR THE MEASUREMENT OF RADIO INTERFERENCE AND THE DETERMINATION OF TOLERABLE LEVELS OF INTERFERENCE

(Study Programme 4B/I)

(1966)

The C.C.I.R.,

CONSIDERING

(a) that it is necessary to know the influence of radiation from electrical apparatus and installations on radio services, especially broadcasting and mobile services, as a basis for interference suppression;

(b) that the establishment of standards for the measurement of radio interference from electrical devices and installations and for the permissible levels of this interference have been found necessary in many countries;

(c) that it would be of great practical advantage if the national regulations concerning the interference producing properties of electrical equipment could be the same in all countries;

(d) that the C.I.S.P.R. has done valuable work in this field and produced recommendations and reports towards international standardization;

(e) that many Administrations, Members of the I.T.U., are familiar with the work of the C.I.S.P.R. and its recommendations and reports, and that these have been studied within the C.C.I.R.;

UNANIMOUSLY RECOMMENDS

that as far as possible, Administrations should take into account the recommendations, reports and publications of the C.I.S.P.R., and that national regulations concerning interference suppression should be based upon the measuring methods and apparatus described in the following C.I.S.P.R. documents.

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REPORTS OF SECTION A (EMISSION)

REPORT 176-1 *

COMPRESSION OF THE RADIOTELEPHONE SIGNAL SPECTRUM IN THE HF BANDS

(Question 2/1)

(1963 – 1966)

The C.C.I.R. has studied a number of systems for the compression of the radiotelephone signal spectrum and particularly the possibility of using such systems in the HF bands.

The French Administration (Doc. I/21, Geneva, 1962), described a system invented by Marcou and Daguet which provides quite good articulation and, as developed presently, occupies about one third of the usual bandwidth on stable transmission channels such as those provided by submarine cables or wideband radio-relay systems, but is eight times more sensitive than a normal single-sideband circuit to variations in the attenuation of the transmission medium.

The United States (Doc. I/27, Geneva, 1962), discussed two systems and later examined a number of other systems **. Systems such as the time assigned speech interpolation (TASI) scheme, are only useful when a large number of channels are involved. Other systems, some of which theoretically require only very narrow bandwidths, lack naturalness and, in some cases, all personal inflexions are removed and information about the personality of the speaker is not conveyed.

Generally, these systems cannot be used with time-varying channels, i.e., with channels in which variable propagation conditions introduce amplitude or phase distortion.

Systems using pulse-code modulation, which may be used in very severe propagation or noise conditions, do not usually conserve bandwidth, when only one or a small number of channels are coded in the same code sequence.

The most promising field is the use of single-sideband transmission with reduced or suppressed carrier. This system can yield almost twice as many voice channels in the same spectrum as compared with double-sideband systems, and unlike a number of other spectrum reducing systems, it is well suited to HF radiotelephone transmissions. The single-sideband signal provides a better signal-to-noise ratio, with an appropriate receiver, and is considerably less affected by selective fading ***.

It has been shown theoretically that for time-varying channels, the most promising systems would make use of a small part of the available channel width to transmit some kind of pilot carrier which would be used, at the receiving end, to determine continuously the phase and amplitude properties of the channel and automatically control compensating devices in the receiver. In these systems the bandwidth allocated to the auxiliary channel depends upon the rate of variation of the parameters representing the properties of the channel. This bandwidth, if it is contained within the total available bandwidth, reduces the bandwidth available for the transmission of the original signal. But this latter bandwidth could then be considered as being that of a channel having stable characteristics, the capacity of which could be evaluated by the usual methods. It would be very desirable to encourage research and studies of such systems.

One system using an auxiliary channel is described in Report 354, in which the signal is heavily compressed at the transmitter and information concerning the degree of compression is continuously conveyed by frequency-modulation over a separate narrowband channel to restore the original signal shape at the receiver. Though not in itself producing bandwidth compression

* This Report was adopted unanimously.

** Beery, W. M. and Nesenbergs, M., *National Bureau of Standards, Report 7296.*

*** See Recommendations 100 and 330.

the ability to communicate over a noisy channel is considerably enhanced. Furthermore, the possibility has been demonstrated practically that, by partial overlapping of several such channels, spectrum economies of up to 50% are possible.

The system is particularly effective where fading occurs in the propagation path.

REPORT 177 *

COMPRESSION OF THE RADIOTELEGRAPH SIGNAL SPECTRUM IN THE HF BANDS

(Question 3/I)

(1963)

1. Introduction

The principles of bandwidth reduction have been used intuitively since the very beginning of telegraphic communication. Codes were developed to provide for the transmission of a given language in the least amount of time and bandwidth. In very limited bandwidth systems, such as transatlantic cables, use was made of three levels of amplitude and the principles of synchronous detection (regeneration) employed.

In recent years, in HF telegraphy, the trend has been toward the reduction in errors rather than the reduction of bandwidth. It is reasonable to assume that high-frequency telegraph systems will continue to use somewhat greater bandwidth than theoretically necessary (for example, the use of F1 in place of A1 emission), to overcome the unstable and noisy conditions met with in HF telegraph communication. (See Doc. III/33 (U.S.A.), Geneva, 1962.)

2. Phase-change signalling systems

Phase-change signalling systems, using two or more levels, have been investigated and can be used to yield a narrow-band transmission system. Unfortunately, their use at HF has not been successful, because of the phase instability of the propagation medium. It does not appear that present phase-change techniques can be recommended for HF telegraphy.

3. Digital signalling systems which employ three or more levels of amplitude, frequency-shift or phase-change

Digital signalling systems which employ three or more levels of amplitude have been investigated. It has been found that a system employing four amplitude levels has a signal-to-noise disadvantage when compared to a two-level system in the same bandwidth. While the bandwidth may be reduced for the same capacity, the higher power required, or the net reduction in signal-to-noise and disadvantages due to multipath transmission, lead to the conclusion that systems using several levels of amplitude are not particularly desirable for HF telegraphy. On the other hand, systems using four frequencies with a spacing of 800 Hz have been widely used and are successful. A somewhat similar system is now proposed using four frequencies with a spacing of only 80 Hz. Diplex keying, with 10 ms elements, is used

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* This Report was adopted unanimously.

on each channel with the two channels synchronized. A net gain of 7 dB in signal-to-noise ratio is realized by the system because of the reduction in bandwidth. With respect to phase-change systems, the previous remarks with regard to HF propagation apply.

4. Coding techniques which provide either message compression or error reduction, or both

Coding techniques have been examined in great detail, particularly since the mathematical development of communication theory. The principal emphasis has been on error reduction for HF telegraph systems rather than the reduction of time or bandwidth. At the present, the best system in general use seems to be the ARQ constant ratio code with feedback for error correction. Numerous techniques are being investigated to increase the volume of information transmitted over each channel, and it is expected that some of these techniques will be applied to reduce either the time of transmission or the bandwidth.

REPORT 178-1 *

POSSIBILITIES OF REDUCING INTERFERENCE AND OF MEASURING ACTUAL TRAFFIC SPECTRA

(Study Programme 5A/I)

(1956 – 1959 – 1963 – 1966)

Summary

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

(a) Interference can never be zero, for the spectrum of any actual signal cannot be zero in any frequency interval; it can be zero only at discrete frequencies.

(b) If the receiver subject to interference can be assimilated to a substantially rectangular pass-band quadripole and it is tuned far enough away from the centre of the spectrum, and if the consecutive signal amplitudes are independent and not correlated, the interference merely adds additional noise to the inherent thermal noise of the receiver.

(c) If the actual signal fulfils the above conditions, its spectrum may be determined by means of an analyzer, and reproducible stable results can be obtained if the analyzer is followed by a quadratic integrator.

(d) If the signal does not fulfil these conditions, the measurements will be unstable, both as regards individual measurements made with the same analyzer and measurements made with different analyzers.

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

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

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* This Report was adopted unanimously.

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

Gabor, after choosing particular definitions for signal duration and bandwidth, showed that the best elementary signal in those respects was a signal having the shape of a Gaussian curve. Such a shape can be approached, as closely as required, by using multiple-section filters, either with a very simple iterative filter section or non-iterative sections, although a large number of sections introduces a signal delay which is the only parameter limiting the practical application of the method. Nevertheless, delays of not more than one word of medium length should be very helpful in reducing out-of-band radiation. Delay is apparently inevitable whenever endeavours are made to compress frequencies or to reduce out-of-band radiation.

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

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

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

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

1. Introduction – Possible ways of examining interference problems

The number of radio channels which can be used in a given frequency band depends essentially on the spacing required between adjacent channels. Leaving aside various phenomena and circumstances which necessitate an increase in spacing, such as field fluctuations, the minimum spacing is determined by the interference produced by each channel in neighbouring channels. If the bandwidth occupied by the emissions, and consequently the out-of-band powers as defined in Recommendation 328-1 were known, it would then be possible to determine roughly the minimum necessary spacing between two frequency assignments. But, without knowledge of additional data, such as the rate of decrease of the energy outside the band limits, the power definition of the occupied bandwidth is not sufficient for the purpose of determining channel spacing.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The second function might be called the switching spectrum; it depends on the switching instants and on coefficients which themselves contain all the information. In complex terms, this spectrum function is equal to the sum of the vectors, of which the length is equal to the coefficients and the phase is proportional to the frequency and the times of switching.

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

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

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

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

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

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

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

However, the switching spectrum is a periodic function of the frequency without a constant term when the switching times are uniformly spaced; the result is, that the spectrum has the shape of the elementary pulse spectrum, multiplied by a periodic function which depends mainly on the information transmitted. Considering the part of the spectrum falling within the (not too narrow) passband of a receiver subject to interference, the average level of the voltage induced in this receiver thus depends primarily on the shape of the elementary pulse spectrum, whatever the time during which the whole receiving system integrates the voltage or the power.

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

If, therefore, we wish to measure easily and rapidly the spectrum emitted by a transmitter which is designed to send out continuous signals (a radiotelephone transmitter, for example), it suffices to apply a thermal noise of suitable power to it, instead of its normal signal. This method, which is indicated in Recommendation 328-1 (§ 2.4) as elsewhere, is the simplest in theory.

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

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

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

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

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

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

Hence, whatever real signal is transmitted, we must always consider a spectrum represented by an entire function, that is to say, extending to infinity and vanishing only at discrete frequencies (which may be an enumerable infinity), but can never identically vanish in any frequency interval, no matter how small it may be.

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

(a) The problem of interference will always exist. Since the spectrum of an actual signal cannot be zero in any frequency interval, any receiver tuned close to the carrier of any actual emission receives energy therefrom. If the frequency difference is large enough, this energy may be small, and sometimes negligible, but it can never be zero.

(b) The effect of interference on a receiver cannot be assessed if we know merely the energy received from the interfering station. It will depend on the nature of the signal transmitted and on the kind of receiver.

Only in one case is the effect of the interfering station very simple; when the receiver passband can be approximated to a rectangular band, and is tuned reasonably far away from the centre of the interfering spectrum. If, in addition, the interfering signal can be represented by successive uncorrelated, independent values, the interference will approximate to thermal noise. It will merely increase the inherent channel noise, but, for equal power, it will have the maximum effect on the loss of capacity of the channel.

(c) If the signals transmitted can be regarded as represented by a series of uncorrelated values, statistically independent of each other, it is possible to measure the spectra of the random signals and to obtain stable results, readily comparable with those obtained by measuring the spectrum of an elementary signal or of the periodic elementary signals applied to the same transmitting system, provided that the spectrum analyzer is followed by a linear, or preferably, by a quadratic integrator.

(d) On the other hand, if the successive amplitudes of the random signal are correlated, its spectrum oscillates around the spectrum of the elementary signal and cannot show any stability, whether the same spectrum analyzer is used for successive measurements or a

different analyser is used. The oscillations have a complicated relationship with the bandwidth and filter characteristics of the analyser, unless the bandwidth is extremely small. In this case, the overall time of measurement may be far too long for the whole to remain coherent and reproducible. It is then preferable to replace such a signal for measurement purposes, either by white noise modulating the transmitter (which is possible with a radiotelephone transmitter), or by a periodic signal (which is generally possible for radiotelegraph transmitters). Laboratory measurement of radiotelegraph spectra is often effected by means of periodic elementary signals; this provides discrete points of the spectrum of the single pulse, which is the envelope of the line spectrum of the periodic pulses.

(e) The problem of reducing interference or out-of-band radiation is reduced to the problem of finding the elementary signal which, transmitted by the same system, would produce minimum interference.

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

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

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

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

3. Reduction of out-of-band radiation

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

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

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

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

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

A well-known practical example is that of the signal directly representing speech. This signal has been studied by many authors who have shown that, for a fairly long period of time and a fairly large number of different voices, its statistical distribution was approximately Gaussian, in this respect approaching white noise, which exactly satisfies the mathematical conditions posed above. The speech spectrum can thus be reduced to a very low amplitude outside a band which is easy to determine, but it cannot be reduced to zero, as a given conversation begins at a finite moment. The reduction of out-of-band radiation can be achieved with the help of a filter without too much deterioration of articulation: the reduction is greater as the number of sections is increased, the increase of this number being the only means available of increasing the asymptotic slope of the filter. The signal delay, which increases with the number of sections, is thus all the greater as the out-of-band radiation is reduced. Some of these latter properties are well known to engineers; the very general way in which they have been obtained shows that they are independent of any hypothesis on the exact nature of the signal and the circuits used.

Unlike telephone signals, telegraph signals, which are quantized with only two distinct levels, cannot approximate a Gaussian distribution; they are also prolific sources of out-of-band interference.

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

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

4. Reduction of bandwidth

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

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

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

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

Gabor then shows the existence of a relation between these two quantities, similar to an uncertainty relation, according to which their product cannot be less than unity. Since our aim is to find an elementary signal with a minimum duration and as narrow a spectrum as possible, the required conditions must be fulfilled, in the Gabor sense, by signals which make the uncertainty product near to unity. It has recently been shown that this relation is only exact when the spectrum function is zero for frequency zero [8]. This is not usually so, but in the radio case under consideration where the r.m.s. spectrum width is negligible with respect to the carrier frequency, the spectrum energy is almost zero for frequency zero and the Gabor relation is fully applicable. The corrective term should not be considered unless the same theory is to be applied, for example, to carrier frequency telegraph systems, with which this Report makes no attempt to deal.

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

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

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

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

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

Chalk [13], Gourevitch [17] and Ville [19] have determined the form that a pulse of finite duration should have, so that a given frequency band contains the maximum energy. Gourevitch has also determined the bandwidth containing 99% of the total energy for various forms of pulses. It has been shown also that the sine-squared shaped pulse, although occupying a wider band than the trapezoidal pulse, has the advantage of a faster decrease of its power spectrum components outside the occupied bandwidth, and therefore would produce smaller interference for sufficiently wide channel spacing [18]. But these authors have not considered the concept of the signal. A sufficiently delayed Gaussian-shaped impulse would give a much faster decrease of the power spectrum components than any of their optimum signals of finite duration.

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

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

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

In conclusion, it is well to cite some of Gabor's further researches on other forms of signals, as they may give rise to complementary studies. Considering that an exact Gaussian signal is unattainable, Gabor shows that the signal, which is zero outside a certain time interval and which has the smallest " effective bandwidth ", is represented by half a sine-wave; reciprocally, the signal with the shortest " effective duration " has a half-sine-wave spectrum. For these two reciprocal forms, the uncertainty product is only 1·14, which is only a little higher than the theoretical optimum. Gabor remarks that " sine-squared " signals give substantially similar results. Use of this sine-squared shape is justified in television by power considerations, and it is closer to the Gaussian optimum. Wheeler and Loughren [11] were the first to propose the use of clipped sine-wave signals for television, but their justification was empirical.

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

Slepian and Pollak [24] have made a study of an enumerable set of functions possessing the following properties:

- they have a limited spectrum, are orthonormal over the whole of the real axis and their set is complete in the space of limited spectrum functions;
- they are orthogonal in a finite interval, centred on the origin, and their set is complete in the space of functions integrable in absolute square over the same interval.

Thus, this system is most suitable for representing signals, either with a limited duration or with a limited spectrum, and for the study of the effect of signal filtering both in time and in frequency-space.

Landau and Pollak [25] have shown how such a sequence lent itself to the study of the problems, raised by the Pauli-Weyl-Gabor uncertainty relation, to the selection of optimum signal elements and to other similar problems. These methods could almost certainly be used in solving many practical problems relating to signals and interference.

In a later paper [26], the same authors have proved that band-limited functions, containing all but a fraction ε^2 of their energy in a finite interval of time T can be expanded in a series of 2 WT "prolate spheroidal wave functions", with a total integrated squared error less than 12 ε^2. The $(\sin t)/t$ functions are not suitable for this purpose. These results will help to resolve some difficulties related to the practical application of the sampling theorem, to which we alluded in § 3 of this Report.

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

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

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

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

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

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

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

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

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

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

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

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

In practice, all existing receivers are designed to receive and decode the desired signal as well as possible. Protection is usually envisaged against noise, rarely against interference of other kinds, which may be very different, except, for instance, with multiplex, in which the adjacent channel belongs to the same system. Now, since interference is inevitable, it would conceivably be of advantage, in some cases at least, to determine the receiver characteristics to suit both the signal to be received and the interference. This will be feasible, only if the interference is of a particular kind, or at least has characteristics of a certain kind. It is inconceivable that the receiver should reject an interfering signal by making a distinction between it and the wanted signal, if it does not in some sense " know " some of the characteristics of the interference. Protection will be the more effective, the better the receiver "knows" these characteristics. To realize this, it will suffice to consider an obvious extreme case, namely, when the interfering signal is sinusoidal, in the band of a signal such as a radiotelephone signal. If we know accurately the frequency (stable) of the interference, the only parameter on which it depends, we shall be able to filter it by a narrow filter neutralizing a very small receiver frequency band without, in practice, affecting, as we know, the reception of the wanted signal.

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

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

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REPORT 179 *

BANDWIDTH OF RADIOTELEGRAPH EMISSIONS A1 AND F1

Evaluation of interference produced by these emissions

(Study Programme 5A/I)

(1959 - 1963)

1. Introduction

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

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

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

2. Spectrum distribution and bandwidth occupied by F1 emissions

The first document (I/23 (Japan), Geneva, 1958), describes the spectrum distribution of F1 emission in detail, and deals with the occupied bandwidth.

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

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

where

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

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

The effect of the build-up time/decay form of the keying signal on the microscopic shape of the spectrum has been studied. The study has shown that this effect was small for values of $D\tau$ less than 0·15 or between 1 and 5. When the mark and space durations are not equal, the form of envelope varies widely with the product of $D\tau$ by the shortest signal duration, but it is always similar to that produced by reversal signals (dots), with the same build-up time.

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

* This Report, which replaces Report 97, was adopted unanimously.

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

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

where W_0 = total power
and D, m, x and u are as before.

Integrating the above formula (2), between suitable limits, we obtain the total power W' of the components which lie outside the specified frequency band. Fig. 3 represents values of the bandwidth calculated in terms of m and $2D\tau$, for $W''/W_0 = 0{\cdot}01$ and $W''/W_0 = 0{\cdot}001$.

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

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

$$L = D\left\{2 + (3 - 4\sqrt{\alpha})\, m^{-0{\cdot}6}\right\} \tag{3}$$

where α = build-up time/signal duration.

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

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

3% for $\alpha = 0$; $2 \leqslant m \leqslant 20$
9% for $\alpha = 0{\cdot}08$; $1{\cdot}4 \leqslant m \leqslant 20$
10% for $\alpha = 0{\cdot}24$; $2 \leqslant m \leqslant 20$

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

Finally, Fig. 4 shows a fairly good agreement between formula (3), and the results of measurements made on periodic or random signals with bandwidth measuring equipment of the type described in Recommendation 327–1, § 1.2.

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

The second document (I/31 (U.S.A.), Geneva, 1958), gives a detailed description of the spectral distribution of A1 and F1 emissions.

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

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

3.1 *Spectra and filtering of A1 emissions*

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

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

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

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

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

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

$\frac{\text{Length of flat portion}}{\text{Length of signal element}}$	0% (sinusoidal signal)	50%	90%	100% (rectangular signal)
$T = \frac{\text{6 dB low-pass bandwidth}}{\text{Fundamental keying frequency}}$	1·6	3·2	16	∞

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

3.2 *Spectra and filtering of F1 emission*

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

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

3.3 *Adjacent channel interference*

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

Interfering keyed emissions produce at the receiver output:

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

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

R = minimum ratio of wanted-to-unwanted carrier amplitudes at the receiver input, necessary for satisfactory reception;

r = minimum amplitude ratio of the wanted signal response to the maximum response to the unwanted signal at the output of the intermediate frequency amplifier, necessary for satisfactory reception.

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

Class of emission for the wanted signal	Quality of reception (r)	
	Interference not objectionable	Wanted signal fairly readable
Radioteleprinter F1	2	1·5
Commercial radiotelephone.	2 to 10	0·1 to 1
High quality radiotelephone (or music). . . .	100	2 to 10
Facsimile A4	30	4
Facsimile F4	6	2

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

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

$\triangle f$: half the frequency shift ($\triangle f = D$ from Recommendation 328–1) (Take $\triangle f = 0$ for amplitude-modulation).

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

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

f_c : cut-off frequency at 6 dB point of low pass filter.

f : frequency difference between the wanted and unwanted carriers (centred carriers).

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

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

F : 6 dB bandwidth of intermediate-frequency of the receiver.

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

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

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

Fig. 8 shows some results obtained with this formula.

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

4. Measurements on spectra of F1 signals

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

5. Methods permitting the realization of the bandwidth limitations given in Recommendation 328–1

In Doc. I/6 (Federal Republic of Germany), Geneva, 1962, it was shown that the bandwidth limitations, set forth in §§ 2.1 and 2.5 of Recommendation 328–1, may be obtained in practice by the application of the following techniques:

5.1 filtering of the telegraph signals applied to the input to the transmitter by means of filter sections, usually of simple types (most frequently low-pass), whose characteristics and number suit the telegraph speed;

5.2 amplification of the keyed signals in a series of stages, in which a sufficient linearity is assured, both by the choice of type of amplifying stage (cathode-followers and grounded-grid amplifiers, devices which, by themselves, involve a certain degree of negative feedback), by properly adjusting the working point of the high-frequency amplifiers, and by the use of special valves with more linear characteristics;

5.3 negative feedback applied, either to a maximum of three stages of the high-frequency amplifying chain, or between the output of the transmitter and the telegraph signal input, requiring in the latter case, detection and filtering of the HF signal envelope within the loop.

The limitations of Recommendation 328–1 are only just realized, except at the lowest telegraph speeds, where they were exceeded by 3 dB with a high-frequency amplifier having a linearity, with respect to third-order intermodulation products, of —35 dB.

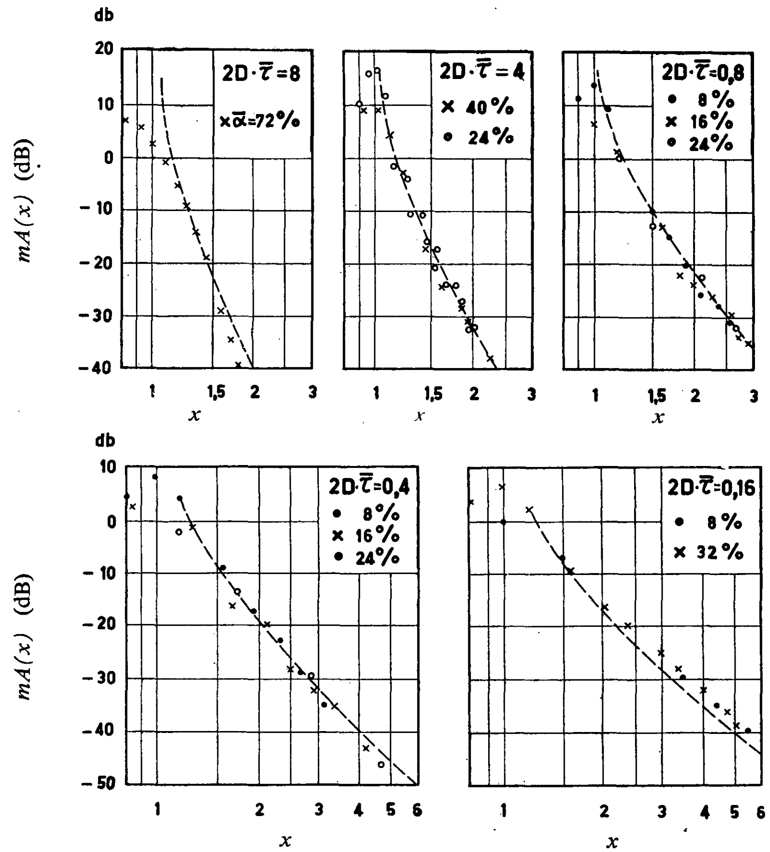


FIGURE 1 – *Spectra of F1 emissions*

— — — — — Calculated from empirical formula (1).

• ○ × Measured points.

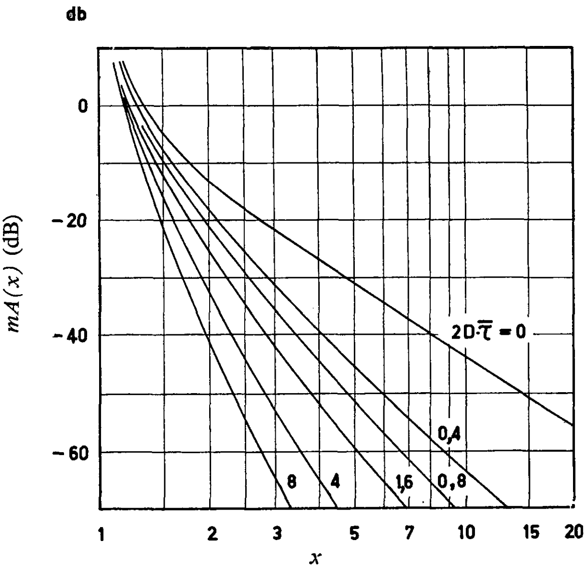


FIGURE 2

Spectrum distribution of F1 emission calculated from empirical formula (1)

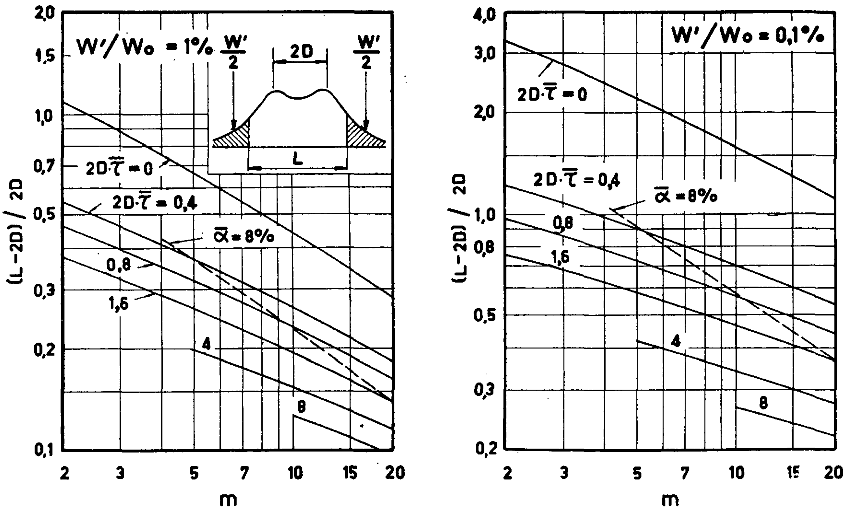


FIGURE 3

Bandwidth calculated from formula (2)

W_o = total power.

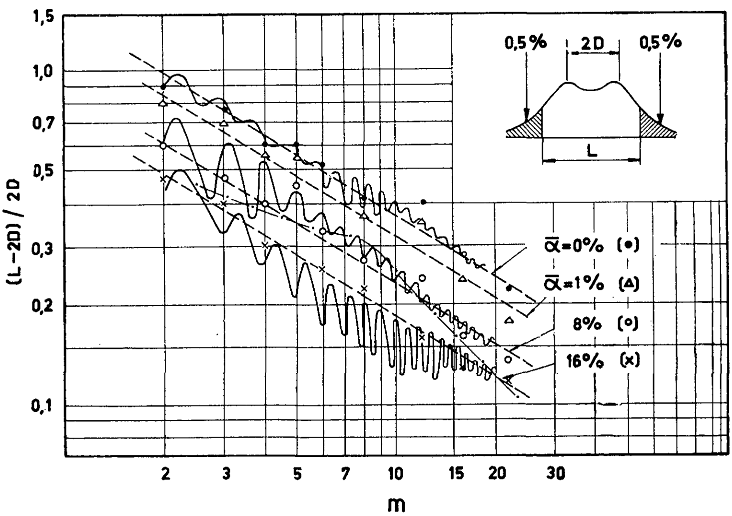


FIGURE 4

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

— · — · — · — Calculated from the formula given in Recommendation 328-1.

— — — — Calculated from formula (3).

———————— Calculated from spectra obtained from spectrum analyser.

• Δ ○ × Measured points obtained with the bandwidth measuring device.

$\bar{\alpha}$ Build-up time/signal duration.

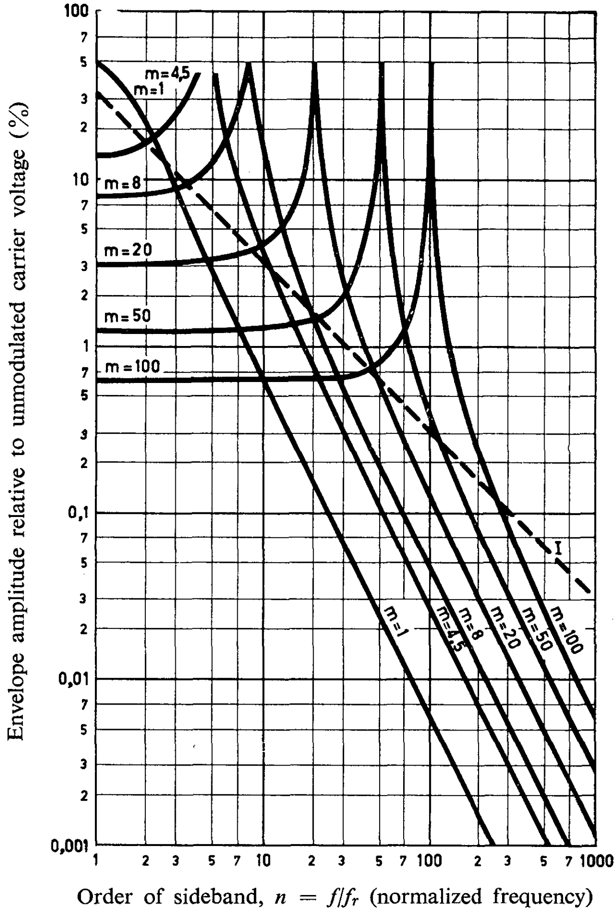


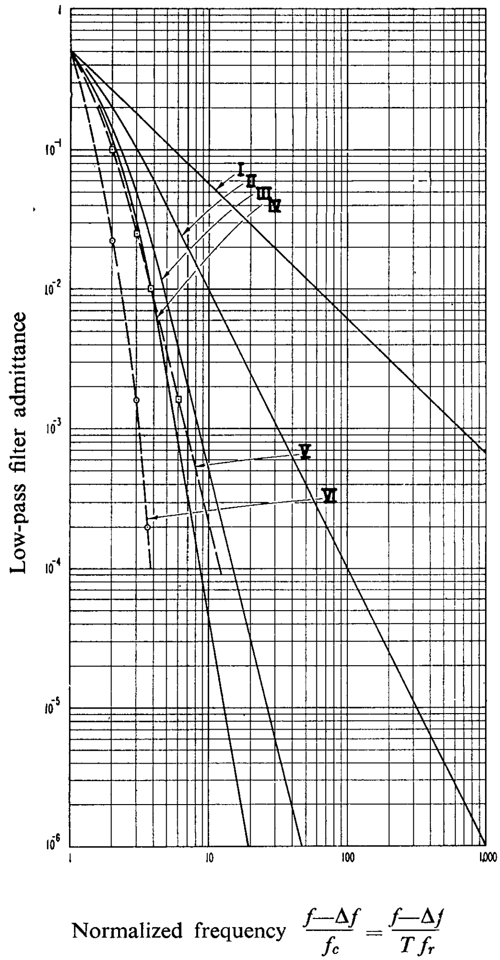
FIGURE 5

Envelopes of square-wave frequency-shift keying spectra

Curve I: A1 square-wave.

Asymptotic formula, good in linear region of curves:

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



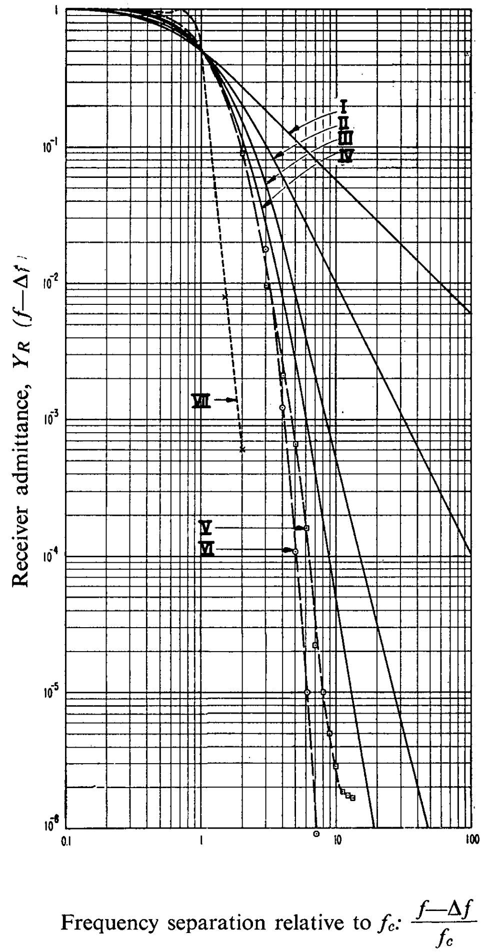


FIGURE 6

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

Calculated curves: Isolated, identical RC filters.

I 1 section

II 2 sections

III 4 sections

IV 6 sections

Measured curves:

V 4-section RC filter with feed-back for optimum response.

VI 4-section LC filter with opti mum transient response.

FIGURE 7

Receiver admittance curves, normalized to the 6 dB cut-off frequency ($f_c = F/2$) for obtaining quasi-steady-state response

Calculated curves:

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

Measured curves:

V Good receiver with 4 tuned stages, i.e. two sets of coupled circuits, measured at high frequency so that the radio-frequency stages are not effective.

VI Good receiver as above, but measured at low frequency so that the radio-frequency stages are effective.

VII Seven-section electro-mechanical filter.

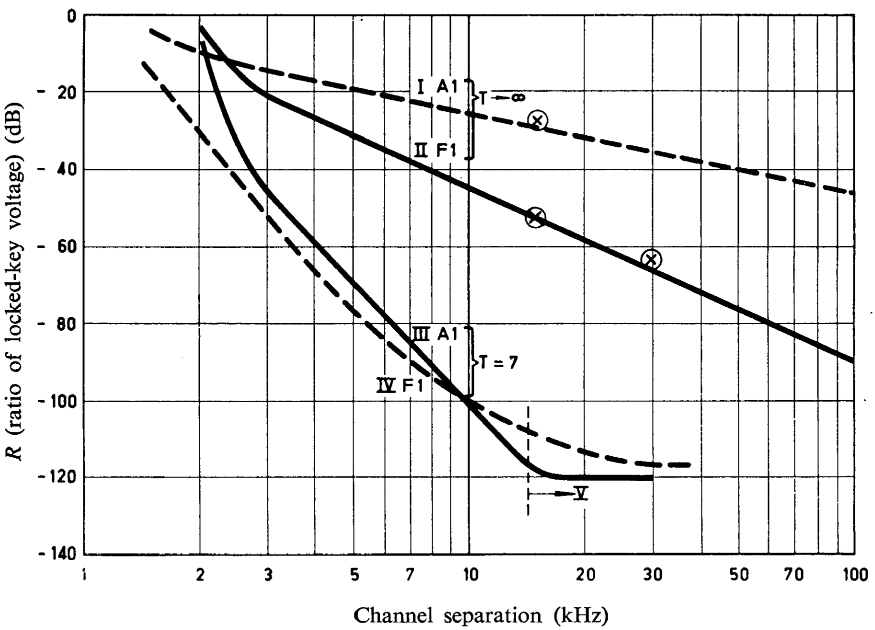


FIGURE 8

Values of R for the transmitter and receiver characteristics indicated

Receiver: 2 sets of double-tuned coupled circuits in the IF section with a 6 dB bandwidth of 1·5 kHz (average voltage bandwidth 1·6 kHz) with an assumed IF output ratio, *r*, of 2 (see § 3.3).

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

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

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

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

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

⊗ : Experimental points.

Line V: Limitations in *R*, for frequency separation greater than 15 kHz, are caused by limitations of maximum receiver selectivity.

REPORT 180-1 *

FREQUENCY STABILIZATION OF TRANSMITTERS

(Study Programmes 8A/I and 9A/I)

(1963 - 1966)

Contributions concerning Study Programmes 8A/I and 9A/I were presented in Docs. I/2 (Portugal), I/8 (United Kingdom), I/31 (P. R. of Poland) and I/33 (Rev.) (U.S.S.R.), Geneva, 1962.

1. Undesirable departures of the characteristic frequency of a radio emission from the reference frequency may occur for the following reasons:

1.1 incorrect initial setting of the frequency;

1.2 drifts due to ageing processes in the piezo-electric crystal or the oscillator circuit;

1.3 sudden changes in frequency, which occur on changeover from one drive-unit to another, which is nominally at the same frequency, particularly if in such apparatus there is no means of adjusting the frequency;

1.4 jumps in frequency due to vibration or mechanical shocks;

1.5 cyclic variations, daily or seasonal, of the atmospheric conditions (temperature, humidity and pressure), affecting the piezo-electric crystal and oscillator circuit;

1.6 variations of temperature in the oven due to the operating cycle of the thermostat;

1.7 variations in power supply voltage;

1.8 variations in the instantaneous, or mean level, of the output signal producing carrier flicker by feedback mechanisms, mains regulation and other means;

1.9 variations in oscillator load.

It has been suggested (Doc. I/2, Geneva, 1962), that variations of the characteristic frequency from its mean value should be determined during a specified period of time, which shall be as short as possible compared with the period of time which has been used to determine the mean characteristic frequency.

It has been further suggested that random variations of characteristic frequency follow a Gaussian law. However, measurements carried out to establish the statistical properties of the frequency variations (Study Programme 8A/I, § 1), do not confirm completely that the instantaneous values of frequency follow such a law.

2. In recent years, a noticeable improvement has been observed in the stability of certain categories of transmitter. Observations carried out by at least one Administration, over the period of 10 years since 1950, show an improvement in stability of the order of 2 to 1. Further observations have been made by the United Kingdom and the C.C.R.M. in Brussels since 1960, and reported in Doc. I/10, 1963–1966. These observations show that a considerable improvement can be obtained by using crystal-controlled oscillators having low temperature coefficients. The ageing drift of the crystals is lower than $0{\cdot}8 \times 10^{-6}$ per month.

On the other hand, master oscillators which are used to control synthesizers, have a long term stability of 1×10^{-8} per month.

The use of improved monitoring and more precise frequency measuring equipment seems to be responsible for the observed improvement. Further improvement in the adjustment of the mean frequency of the oscillator would, however, improve the situation still further even with existing oscillators.

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* This Report was adopted unanimously.

Doc. I/47, (U.S.S.R.) 1963 – 1966, indicates that by using low-power active elements and by improving the methods of temperature stabilization, it is possible to obtain long-term (six months) stabilities of 2×10^{-7}. This result can be obtained with an equipment weighing approximately 5 kg.

Frequency measuring equipment is available at moderate cost, with built-in frequency standards, having an accuracy of 10^{-7} or even better. Its use is becoming more general and this should contribute to a large extent in improving the adjustment of oscillators. It is recommended that the accuracy of such equipment be checked periodically, by comparison with standard-frequency emissions.

3. Primary crystal oscillators are nowadays commonly used as sources of constant frequency. The following Table shows that the quality and price of such oscillators can vary within wide limits:

Type of oscillator	Temperature compensation	Stability ($\times 10^{-6}$)	Approximate relative price
Ordinary crystal	no	± 100	1
Crystal with low temperature-coefficient.	no	± 20(1)	2
Ordinary crystal	yes	± 5 to 1	3
Improved system, with circuits in oven	yes	± 0·5	4 to 6
Synthesizer	yes	± 0·01	20(2) to 100

(1) Above 1 MHz only. Below 1 MHz, the figure is ± 50.
(2) The lower limit of 20 is for a single-frequency synthesizer.

It would be advantageous to know the approximate weight of the equipment, with and without power supplies.

It would be preferable to distinguish between short-term and long-term stabilities, by specifying the periods of time to which they apply.

A very high stability can be achieved, over a wide range of frequencies, if a fixed-frequency oscillator of extremely high performance is used to synthesize the characteristic frequency. This frequency is obtained from the single frequency-source by multiplication, division and combination processes; the relative stability is thus equal to that of the source.

Certain systems incorporate an interpolation oscillator, which permits the use of frequencies between the discrete frequencies obtained by synthesis. This interpolating oscillator, which usually covers only a small frequency range, can be made very stable, but must inevitably have an effect upon the stability of the system.

Although the prices of synthesizers are comparatively high, they are particularly well adapted for replacing a great number of single-frequency oscillators, in services requiring frequent changes over a large range and number of frequencies. Automatic or remote-control facilities may be added to synthesizers, to make the application of the system still more flexible.

Synthesizers have also been used with success for television transmitters, in which the tolerances required for a high-grade service are far more severe than those needed from the standpoint of economy of bandwidth alone (Doc. I/31, Geneva, 1962). The stability currently attained by such systems is $\pm 10^{-8}$.

Attention has been drawn, however, to certain undesirable effects, which can arise in connection with the process of synthesis (Doc. I/33 (Rev.), Geneva, 1962). Spurious frequency-modulation and intermodulation products are inevitably present at the output, due to the numerous non-linear circuit elements used in forming the signal (multipliers, dividers, mixers and phase-discriminators for automatic frequency control).

Filtering, preferably introduced immediately after the point where undesirable frequency components appear, reduces their level somewhat, but does not necessarily eliminate them.

4. Amplitude-, phase- or frequency-modulated oscillators are very often used in conjunction with a high-stability oscillator to generate the characteristic frequency. They tend to reduce the stability of the whole, particularly when the modulated oscillator contributes to a large extent in generating the radiated frequency, as with transmitters working in the lower part of the 4 to 27 MHz band.

5. It is important to accept, that maintenance of the characteristic frequency within a specific frequency tolerance, requires periodic adjustment of the source, preferably by comparison with standard-frequency emissions.

REPORT 181-1 *

FREQUENCY TOLERANCE OF TRANSMITTERS

(Study Programme 9A/I)

(1963 – 1966)

1. Introduction

Study Programme 9A/I, invites the C.C.I.R. to study further frequency tolerances with a view to achieving a more economical use of the radio-frequency spectrum; to predict what the ultimate values of these tolerances might be under currently known conditions of operation; to report upon the possibilities of achieving these ultimate values consistent with technical and economic considerations; and to indicate which of the currently specified tolerances have already achieved these ultimate values.

Table I is not proposed as a new table of frequency tolerances for adoption by an Administrative Radio Conference. The present Table in the Radio Regulations does not go into effect until 1 January, 1966, and for certain stations, 1 January, 1970. It is, therefore, too early to propose a new table of frequency tolerances.

On the other hand, the greatest difficulty in adopting improved tolerances is the economic problem created by the large number of transmitters in operation and which were manufactured in accordance with existing tolerances. For this reason, and in accordance with Study Programme 9A/I, the following Table has been prepared for certain categories of stations where it can be foreseen that improved tolerances are desirable and feasible for new equipment manufactured in the near future. The intention is to provide guidance for the manufacturer of new equipment so that, at some future date, improved tolerances may be adopted without serious economic injury, because of large amounts of equipment not able to meet the new tolerances.

2. Factors affecting frequency tolerances

The first consideration, with respect to the efficient use of the radio-frequency spectrum, is that the frequency space lost because of instability should be a small part of the necessary bandwidth used for communication. For purposes of illustration, the figure of $\pm 1\%$ of the representative bandwidth has been used to provide a guide to the value of frequency tolerances which may be acceptable from the standpoint of spectrum economy in each case.

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* This Report was adopted unanimously.

Reduction in the frequency bandwidth, lost by instability, is not the only criterion with respect to conservation of radio spectrum. For example, in A3 broadcasting and in other forms of A3 emission, the tolerance should be small enough to reduce common channel interference caused by the beat note between off-frequency carriers. In radiotelephone single-sideband classes of emission, by a number of stations on a single frequency, the tolerance should be small enough to permit the suppression of the carrier and to provide good voice intelligibility without the readjustment of receivers.

There are certain categories of stations which should not be required to meet a strict tolerance for operational and administrative reasons. An example is mobile radar systems, where the administrative problem of rigid frequency assignments is now unnecessary and, from an operational standpoint, interference is reduced by permitting normal manufacturing tolerances to cause a distribution within the assigned bands. Another case is the marine high-frequency A1 telegraph system, where tolerances which will maintain the signals within the allocated frequency band provide operational advantages by permitting these signals to be distributed more uniformly throughout the band, consequently reducing interference in practical operation.

For example, a tolerance of 100×10^{-6} would be appropriate in the band from 4 to 29·7 MHz for low traffic A1 ship stations operating in accordance with Appendix 15, Section A, of the Radio Regulations (Geneva, 1959).

The advantages of tighter frequency tolerances for transmitters cannot, in all cases, be fully realized unless corresponding improvements are made in receivers.

3. Form of the Table

Table I includes categories of stations with respect to which it is believed possible to make recommendations at the current state of development of technique. As studies continue under Study Programme 9A/I, it is hoped that additional categories of stations in additional frequency ranges may be added.

The purpose of the columns is discussed below:

(1) The frequency bands, category of station and class of emission.

(2) A value of necessary bandwidth regarded as representative.

(3) Tolerances which can be attained now or in the near future, taking into account economic and environmental factors. Such tolerances should not be adopted by an Administrative Radio Conference until new equipment, meeting these tolerances, has replaced a major portion of existing equipment.

(4) Ultimate tolerances which will be equal to, or less than $\pm 1\%$, of the representative necessary bandwidth except in unusual circumstances. The choice of these values should take into account system advantages which would be available because of strict tolerances, for example, in A3 broadcasting and the A3J telephony service (see § 2 above). It is not necessary that the tolerances shown be obtainable in the foreseeable future.

TABLE I

Frequency bands and categories of stations	Representative value of necessary bandwidth of emission (kHz)	Tolerance achievable now, or in the near future (Hz)	Ultimate tolerance (Hz)
(1)	(2)	(3)	(4)
Band 535–1605 kHz			
Broadcasting stations	10	10	10
Band 1605–4000 kHz			
1. Fixed stations:			
A3	6	60	60
A3H-A3J	3	10	10
A3A-A3B	3–6	10	10
2. Land stations:			
A3	6	20	10
A3H-A3J	3	20	10
3. Mobile stations:			
(a) Ship stations: A3H-A3J	3	100	20
(b) Land mobile stations: A3H-A3J	3	100	20
(c) Aircraft stations: A3J	3	20	20
4. Broadcasting stations	10	10	10
Band 4–29·7 MHz			
1. Fixed stations:			
(a) Telephone network with several stations on a single frequency: A3J	3	10	10
(b) Other fixed stations	1·7 to 12	10	3
2. Land stations:			
(a) Coast stations:			
A3H-A3J	3	10	10
A7A	3	3	3 (1)
A1	0·1	100	100
Other than A1	1·7	17	17
(b) Aeronautical stations: A3J	3	10	10
(c) Base stations: A3H-A3J	3	20	10
3. Mobile stations:			
(a) Ship stations: A3H-A3J	3	100	20
F1	0·2	10	10 (1)
(b) Aircraft stations: A3J	3	20	20
(c) Land mobile stations: A3H-A3J	3	100	20
4. Broadcasting stations	10	10	10
Band 29·7–108 MHz		(kHz)	(kHz)
1. Land stations (50 MHz)	16	1	
2. Mobile stations (50 MHz)	16	1	
3. Broadcasting FM stations	200	2	2
4. Television stations	6000	2·5 Hz (2)	2·5 Hz (2)

Frequency bands and categories of stations	Representative value of necessary bandwidth of emission (kHz)	Tolerance achievable now, or in the near future (Hz)	Ultimate tolerance (Hz)
(1)	(2)	(3)	(4)
Band 108–470 MHz		(kHz)	(kHz)
1. Land stations:			
(a) Coast stations (156 MHz).	36	3	
(b) Base stations (470 MHz)	36	2·5	0·36
2. Mobile stations:			
(a) Ship stations (156 MHz)	36	3	
(b) Land mobile stations (470 MHz) . . .	36	2·5	
3. Television stations	6000	2·5 Hz (²)	2·5 Hz (²)

(¹) This tolerance is required for reception without automatic frequency control, for narrow-band frequency-modulation telegraph channels.

(²) The tolerance of the sound-channel carrier with respect to the visual carrier frequency is 1 kHz.

REPORT 182 *

DETERMINATION OF THE MAXIMUM LEVEL OF INTERFERENCE THAT IS TOLERABLE IN COMPLETE RADIO SYSTEMS, CAUSED BY INDUSTRIAL, SCIENTIFIC AND MEDICAL INSTALLATIONS AND OTHER KINDS OF ELECTRICAL EQUIPMENT

(Question 4/I)

(1963)

1. Two documents were presented to the Interim Meeting of Study Group I, Geneva, 1962, dealing with special cases of this subject.

2. **Doc. I/3 (Federal Republic of Germany), Geneva, 1962**

This document deals with laboratory tests which have been carried out to determine the effect of impulsive interference on frequency-shift radio-teleprinter transmissions and to determine the maximum tolerable values of the interfering voltage for various values of the wanted signal voltage and for a given level of interference.

A test-signal generator, arranged for frequency-shift emission, was used as a source of the wanted signals, and was connected to the input of a radio-telegraph receiver by a decoupling network. A teleprinter signal distortion indicator was connected to the output of the receiver. The interfering signal, produced by an experimental interference generator, was connected to the decoupling network mentioned above. The shape, amplitude and repetition frequency of the interfering pulses correspond approximately to those which are often produced by industrial apparatus. The shape of impulses chosen, and the duration of a pulse (5×10^{-10} s), ensure that the amplitudes of the spectral components of interfering pulses shall be constant throughout the frequency range from 0 to about 1000 MHz. The interference measuring set was constructed in accordance with the C.I.S.P.R. standards. (C.I.S.P.R. Publication 1,

* This Report was adopted unanimously.

1961. " Specification for C.I.S.P.R. radio interference measuring apparatus for the frequency range 0·15 MHz to 30 MHz ").

The following parameters were maintained constant during the whole series of measurements:

- Class of emission: F1
- Total frequency shift (2 *D*): 200 Hz at 0·1 MHz
  400 Hz at other frequencies
- Telegraph signals: Reversals at 50 bauds
- Receiver type: Traffic receiver, with special telegraph equipment
- Total receiver bandwidth: 1000 Hz
- Cut-off frequency of low-pass filter: 100 Hz.

Table I gives the values of the tolerable interference levels obtained for different levels of the wanted signal, for a distortion of 20% exceeded for 1 in 1000 telegraph signal elements (see Recommendation 331–1, Annex II, § 5.4).

TABLE I

Tolerable levels of impulsive interference for frequency shift teleprinter reception at different levels of the wanted signal

Frequency of reception	Pulse repetition frequency	Level of interfering signals (dB rel. 1μV in 60 ohms) evaluated by the interference measuring set for a wanted signal level (db rel. 1μV) of:				
MHz	Hz	0	+20	+40(1)	+60(1)	+80(1)
0·1	2·5	−14	1·5	17·5	> 21	> 21
	25	− 8	14	31	> 35·5	> 35·5
	250	0	22	38	> 43	> 43
	2500	− 1	20·5	36·5	> 45	> 45
1·3	2·5	− 4·5	10	> 17·5	> 17·5	> 17·5
	25	3	23·5	38	> 38	> 38
	250	9	26·5	41	> 46	> 46
	2500	3	22	39·5	> 49	> 49
10·0	2·5	−12	8	> 23·5	> 23·5	> 23·5
	25	0·5	23	> 39	> 39	> 39
	250	8	32	> 47	> 47	> 47
	2500	4	25·5	47	> 49	> 49
30·0	2·5	− 8	9·5	> 23·5	> 23·5	> 23·5
	25	3	20·5	> 37·5	> 37·5	> 37·5
	250	4	23·5	41·5	> 46	> 46
	2500	2	22·5	41·5	> 48	> 48

(1) All the values preceded by the sign > indicate the maximum output voltage of the pulse generator used. The exact values of the interference are not known.

These results take into account only a restricted number of parameters. More measurements should be made, taking into account the following parameters:

2.1 *System parameters*

2.1.1 *Class of emission*

2.1.2 *Frequency shift*

2.2 *Receiver characteristics*

2.2.1 *Type*

2.2.2 *Intermediate frequency bandwidth*

2.2.3 *Cut-off frequency of the post-discriminator low-pass filter*

2.3 *Wanted signal*

Type and speed of the telegraph signals.

3. Doc. I/4 (Federal Republic of Germany), Geneva, 1962

This document deals with laboratory tests, which have been performed to determine the influence of radio-frequency disturbances on the radiotelephony selective calling system used by the Federal German Post and Telecommunications Administration.

An experimental method is described in this contribution. In conclusion, it can be said that the sensitivity of the calling system to interference of this nature is so small, that the minimum necessary signal level for the selective calling system is smaller than the minimum signal level necessary to give satisfactory understanding of speech.

REPORT 323 *

INTERFERENCE CAUSED BY ELECTRICAL APPARATUS AND INSTALLATIONS ON BOARD SHIPS

(Study Programme 4A/I)

(1966)

Study Group I considered Doc. I/51 (I.F.R.B.), 1963-1966. It appreciated the desirability that the World Administrative Maritime Mobile Radio Conference (Geneva, 1967) obtain from the C.C.I.R. technical data on the level at the receiver input of interference caused by electrical equipment on board the ship on which the receiver is operating.

It noted, however, that no document on the problem had been submitted to the C.C.I.R. XIth Plenary Assembly and that it is accordingly unable to suggest any values for those levels.

It was pointed out, however, that some information is contained in the following documents:

Radio-interference suppression on marine installations
British Standard 1957: 1963 revision (BSI)
issued by: The British Standard Institution,
24/28 Victoria Street,
London S.W.1,
England

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* This Report was adopted unanimously.

Electrical installations in ships, Part I: General requirements. International Electrotechnical Commission (I.E.C.) Publication 92–1; second edition, 1964, issued by I.E.C., Geneva.

In the circumstances, it considers that it is for Administrations themselves to make suggestions to the Administrative Conference in question.

REPORT 324 *

APPROXIMATE METHODS FOR THE DETERMINATION OF BANDWIDTH

(Study Programmes 5A/I and 6A/I)

(1966)

1. In many cases, when essentially determined by the properties of a filter, the slope in decibels per logarithmic unit of frequency of those parts of a spectrum distant from the central part becomes asymptotic to a line of constant slope. This slope can be determined by measuring points at a sufficiently high level to avoid disturbances due to noise and interference.

   However, within parts near to the limits of the occupied band, it is frequently observed that spectra show a slope almost constant in decibels per unit frequency. With this assumption the occupied bandwidth may be approximately evaluated by integrating the power density between a frequency near the assumed limit of the occupied band and infinity. This will not cause a large error provided that the constant value of the slope used in the calculation is determined from measurements made at sufficiently low levels, for instance at levels to be determined between 15 and 35 dB below the reference level as defined in Recommendation 328–1 for each class of emission. A detailed description of this method is given in Doc. I/42 (Japan), 1963–1966.

2. In view of the general use of voltage-indicating spectrum analysers at monitoring stations, the alternative method of measuring bandwidth described in Report 275–1, § 1.3, can be used. In this case, a " 26 dB bandwidth " and a " 6 dB bandwidth " can be used, defined as the width of the frequency bands outside which the levels of all spectral components are 26 dB or more, and 6 dB or more, respectively, below the level of the peak value of the emission as indicated by the spectrum analyser. To determine this peak value, the sweep is made inoperative and the filter bandwidth of the analyser made sufficiently large to accept all significant components of the emission.

   When using the resultant data, due consideration should be given to the fact that the indications obtained are closely related to the characteristics of the spectrum analyser. In general, the resolution of the spectrum analyser should not exceed 1/10 of the bandwidth of the emission.

   It should also be noted that the results obtained by this method have no simple relationship with the occupied bandwidth as defined in No. 90 of the Radio Regulations, Geneva, 1959.

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* This Report was adopted unanimously.

REPORT 325 *

SPECTRA AND BANDWIDTH OF AMPLITUDE-MODULATED RADIOTELEPHONE EMISSIONS

Results of measurements and the shape of the spectrum of single-sideband and independent-sideband radiotelephone emissions with reduced or suppressed carrier

(Study Programme 5A/I)

(1966)

1. Introduction

The occupied bandwidth and out-of-band radiation of amplitude-modulated radiotelephony emissions depend in varying degree on several factors, such as:

- the type of modulating signal used;
- the level of the modulating signal determining the loading of the transmitter;
- the passband which results from the filters used in the audio-frequency stages and in the intermediate and final modulating stages of the transmitter;
- the magnitude of the intermodulation components, mainly those of the third order produced in the radio-frequency stages following the final modulator.

The results of measurements are also dependent upon the passband of the selective measuring device employed and of its dynamic characteristics, such as the integration time of the meter, or other devices used in conjunction with the above selective instruments, to measure the power level of the spectral components.

Measurements on radiotelephone transmitters for single-sideband and independent-sideband emissions with reduced or suppressed carrier have been carried out by a number of Administrations, from which some general conclusions can be drawn concerning the general shape of spectrum emitted by transmitters for such classes of emission, with particular regard to the above factors.

2. Comparative measurements on a class A3B transmitter, modulated in one of its sidebands with white noise or with a series of rectangular pulses having a small duty cycle (Docs. I/43 and I/44 (Federal Republic of Germany), 1963-1966)

Measurements of out-of-band radiation are described, which have been performed on a transmitter of 20 kW peak envelope power, designed for single-sideband and independent-sideband emissions carrying up to four speech channels, each having a bandwidth of approximately 3000 Hz.

Only the lower sideband was used, the upper sideband being suppressed to at least —60 dB by means of the filter incorporated in the transmitter. The carrier was suppressed to approximately —50 dB (class A3J) and the audio-frequency bandwidth was approximately 6000 Hz.

The levels of the intermodulation components of the 3rd and 5th order, which were determined by modulating the transmitter with two sinusoidal oscillations of equal amplitude to a peak envelope power of 20 kW, in accordance with the methods given in Recommendation 326-1 were, at the output of the transmitter, 35 dB or more below the level of one of the modulating oscillations.

The results obtained by modulating the transmitter with a white noise voltage were compared with those obtained by using a series of rectangular pulses having a very small duty cycle.

* This Report was adopted unanimously.

2.1 *Results obtained by using a white noise test signal*

The bandwidth of the noise signal, which was flat within 1 dB from 30 Hz to 20 kHz, was limited only by the filter characteristic of the transmitter; see curve (A) of Fig. 1. In this connection it should be noted that, if the radio-frequency spectrum produced by only one speech channel were to be determined, the bandwidth of the test signal should be limited before it is applied to the transmitter, since its overall bandwidth is considerably larger than the width of one speech channel.

The level of the noise signal at the input of the transmitter had been so adjusted that the peak envelope power was not exceeded for more than about 0·3% of the time. Under these conditions the mean power at the output was equal to about one fourth of the peak envelope power.

The level of the power of the spectral components accepted by the selective measuring device was measured with a true r.m.s. instrument having an integration time of about 1 s. Lower values of the integration time gave rise to unreliable results.

One series of measurements was carried out using an analyser with a bandwidth of about 100 Hz. An analyser with a bandwidth of 3·8 kHz and a very steep attenuation slope was employed for the other series.

The results are shown in Fig. 1, curves (D) and (C) respectively. These curves represent the envelopes of the spectra of the lower sideband, measured in the lower radio-frequency range. Curves similar to those given in Fig. 1 were obtained for the higher frequency range. It should be noted that, in this figure, the centre frequency of the passband of the transmitter is taken as the reference frequency zero; hence, the frequency indicated by $\Delta f = -3000$ Hz corresponds to a frequency of 6000 Hz at the input to the transmitter, whereas the frequency $\Delta f = +3000$ Hz corresponds to the position of the suppressed carrier.

Curve (B) represents the limiting curve specified in § 2.4.2.3 of Recommendation 328–1 for class A3B emissions with four speech channels in operation.

It is seen that, if the spectrum measured with the aid of a narrow-band equipment is, as in the present case, just within this limiting curve, the spectrum analysed by means of wideband receivers will exceed this limit. As wideband measuring equipment does not take account of the fine structure of the spectrum, particularly in the region where its slope is steep, the use of narrow-band devices for such measurements should be recommended.

It can be further concluded from Fig. 1 that the out-of-band radiation starts at a level, nearly equal to the level of the third order intermodulation components, viz. at —35 dB. The out-of-band radiation remains almost constant in the immediate vicinity of the limits of the bandwidth; for frequencies remote from these limits the curve gradually decays, at first proportional to frequency, then reaching an ultimate slope of about 12 dB per octave. In Fig. 2 a linear frequency scale has been used at the abscissa, to illustrate more clearly the envelope of the spectrum mentioned above.

2.2 *Results obtained by modulating the transmitter with a series of pulses with short duration*

The test signal consisted of a train of rectangular pulses with small duty cycle, which is equivalent to modulating the transmitter with a series of correlated sinusoidal oscillations, with nearly equal amplitudes and with frequencies which are integral multiples of the pulse-frequency. The pulse repetition frequency was chosen as 400 Hz and the pulse width as 50 µs.

For these conditions of modulation, the mean power at the output of the transmitter was about equal to 0·8 kW.

In contrast to the spectrum obtained by modulating the transmitter with white noise, the spectrum resulting from this test signal consists of discrete components, spaced 400 Hz apart. The test results are indicated by small triangles in Fig. 3.

2.3 *Conclusions*

As the spectrum consists of discrete components, in the second case, the amplitudes of which are stable, the method using the pulse train has the advantage that accurate and reproducible measurements can be performed with customary narrow-band analysers, the integration times of which are immaterial.

However, two difficulties should be mentioned which are still to be solved:

- to drive the transmitter to its peak envelope power, in certain cases the amplitude of the pulse has to be adjusted to a value such that the pre-amplifier or pre-modulating stages are overloaded, thus causing the out-of-band radiation to be influenced by factors which are not involved in actual traffic;
- due to the fact that the spectral components are correlated, the various intermodulation components at a certain frequency may add or subtract dependent upon the relative phase, thus causing a large unpredictable spread around the curve representing the envelope of the spectrum. Deviations of as much as 5 dB from the results obtained by using a white noise modulating signal have been observed.

3. **Measurements on a class A3J transmitter modulated with white noise** (Doc. I/6 (U.S.A.), 1963-1966)

This document summarises measurements which have been performed on a transmitter adjusted for class A3J operation and having an output power considerably lower than that of the transmitter mentioned in § 2 above.

The level of the third order intermodulation products was about —40 dB at a peak envelope power of 150 W, to which power the transmitter was driven by modulating it by white noise, with a bandwidth limited only by the passband of the filter in the transmitter proper.

The measurements were made with a narrow-band analyser having a passband of 300 Hz.

The results, particularly with respect to the level at which the out-of-band radiation starts, correspond very closely to those obtained from the measurements described in § 2.1.

4. **The envelope of the spectrum of a class A3J emission carrying white noise** (Doc. I/49 (Japan), 1963-1966)

This document contains the result of experimental and theoretical studies on the problem of determining the general shape of the spectrum envelope of a class A3J emission which is modulated with white noise.

The general conclusions mentioned at the end of this section are valid only when the following conditions are met:

- the frequency spectrum of the noise signal, applied at the input to the transmitter, should exhibit substantially a rectangular form such that its width, B, is smaller than the passband that results from the filters used in the subsequent audio-frequency stages and in the intermediate and final modulating stages of the transmitter;
- it is assumed that the audio-frequency noise signal is converted in the intermediate and final modulating stages to radio-frequency components, the frequencies of which are much higher than the value B mentioned above;
- it is further assumed that no appreciable distortion occurs during the modulation processes mentioned above; that is to say, the intermodulation distortion present in the signal at the output of the final modulating stage should be negligible;
- as a consequence of the above assumptions, it should be understood that the out-of-band radiation is caused by intermodulation which occurs in the radio-frequency stages of the transmitter following the final modulator.

The level of the white noise signal is assumed to be adjusted as follows:

Two sinusoidal oscillations with equal amplitude are simultaneously applied at the input to modulate the transmitter components and the corresponding third order intermodulation, α_3, is determined. The level of the noise signal is then adjusted to have a power equal to the total power of the two sinusoidal oscillations.

If the above stipulations are met, it may be concluded:

- that the centre part of the radio-frequency spectrum exhibits substantially a rectangular form and is superimposed on a curve showing the out-of-band radiation which extends symmetrically with respect to the centre frequency (see Fig. 4);

- that the level at which the out-of-band radiation starts depends upon the distortion produced in the radio-frequency stages of the transmitter;
- that the difference α_N between the level of the flat portion of the top of the spectrum and the level at which the out-of-band radiation starts, is generally equal to the level of the third order intermodulation component α_3 (see Fig. 5);
- that the slope, expressed in dB per hertz, of the curve representing the out-of-band radiation, is inversely proportional to the bandwidth B of the noise signal at the input;
- that the slope is constant, at least in the neighbourhood of the limits of the bandwidth, and has a value between 10 and 20 dB per bandwidth B, dependent on the character of the distortion (see Fig. 6);
- that the occupied bandwidth of this type of emission is equal to the width of the main spectrum, provided that α_3 is at least 20 dB;
- that the above conclusions are expected to be applicable for those cases where the modulating signal is similar to white noise, such as radiotelephone emissions using a band-splitting privacy device and multi-channel voice-frequency radiotelegraph emissions.

5. General conclusions

5.1 From the above experiments and theoretical considerations the following conclusions may be drawn with respect to the test conditions to be used for measuring bandwidth and out-of-band radiation of radiotelephone emissions:

- a white noise signal, limited to a bandwidth somewhat larger than the bandwidth resulting from the filters used in the transmitter, is a satisfactory substitute for the modulating signal of multi-channel emissions with a small number of speech channels using a band-splitting privacy device and of multiplex emissions carrying a very large number of speech channels;
- at least for the time being, a white noise signal is preferred to a modulating signal consisting of a series of small rectangular pulses;
- to prevent the transmitter from being overloaded, the peaks of the noise signal at the input shall not exceed the level corresponding to the peak envelope power of the transmitter for a specific small percentage of time e.g. 0·5%.

5.2 With regard to the shape of the power spectrum of a single-sideband emission with suppressed carrier and modulated with white noise, it may be further concluded that:

- the steep part of the spectrum just outside the limits of the bandwidth, follows very closely the attenuation curve of the filters used in the transmitter;
- the difference between the flat portion of the centre part of the spectrum and the level at which the out-of-band radiation starts, is approximately equal to the level of the third order intermodulation components;
- over a small frequency interval in the immediate vicinity of the limits of the bandwidth, the level of the out-of-band radiation may be constant;
- at frequencies remote from the limits of the bandwidth the spectrum decays, at first directly proportional to frequency, then reaching an ultimate slope of about 12 dB per octave.

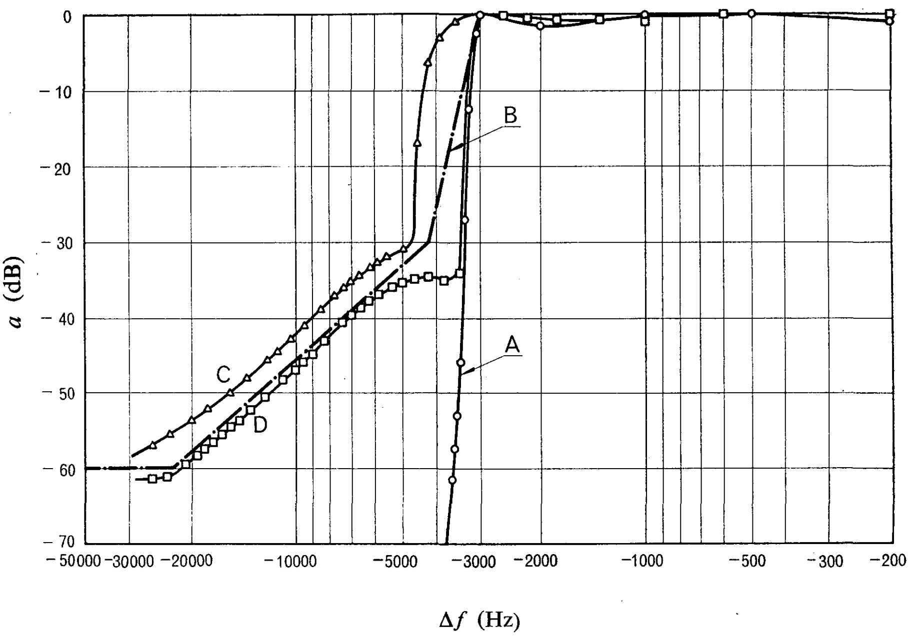
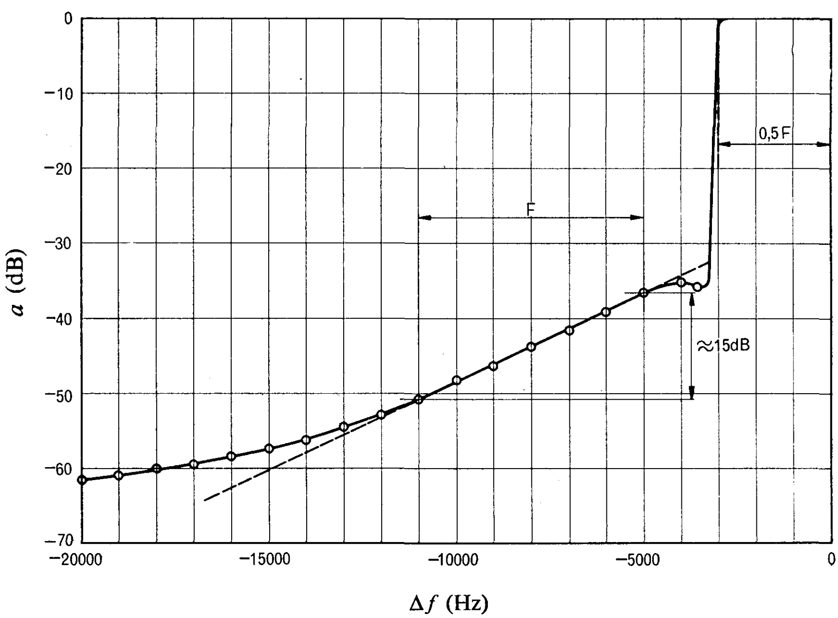


FIGURE 1



F: linear range (slope ≈ 15/F, dB/Hz)

FIGURE 2

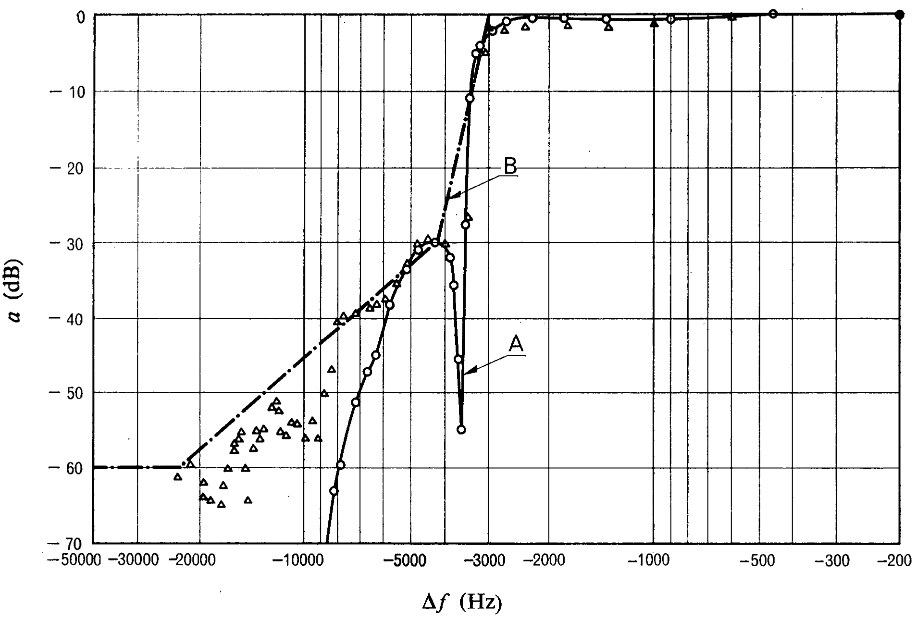

0
— 10
— 20
— 30
— 40
— 50
— 60
— 70
a (dB)
B
A
−50000 −30000 −20000 −10000 −5000 −3000 −2000 −1000 −500 −300 −200
Δf (Hz)

FIGURE 3

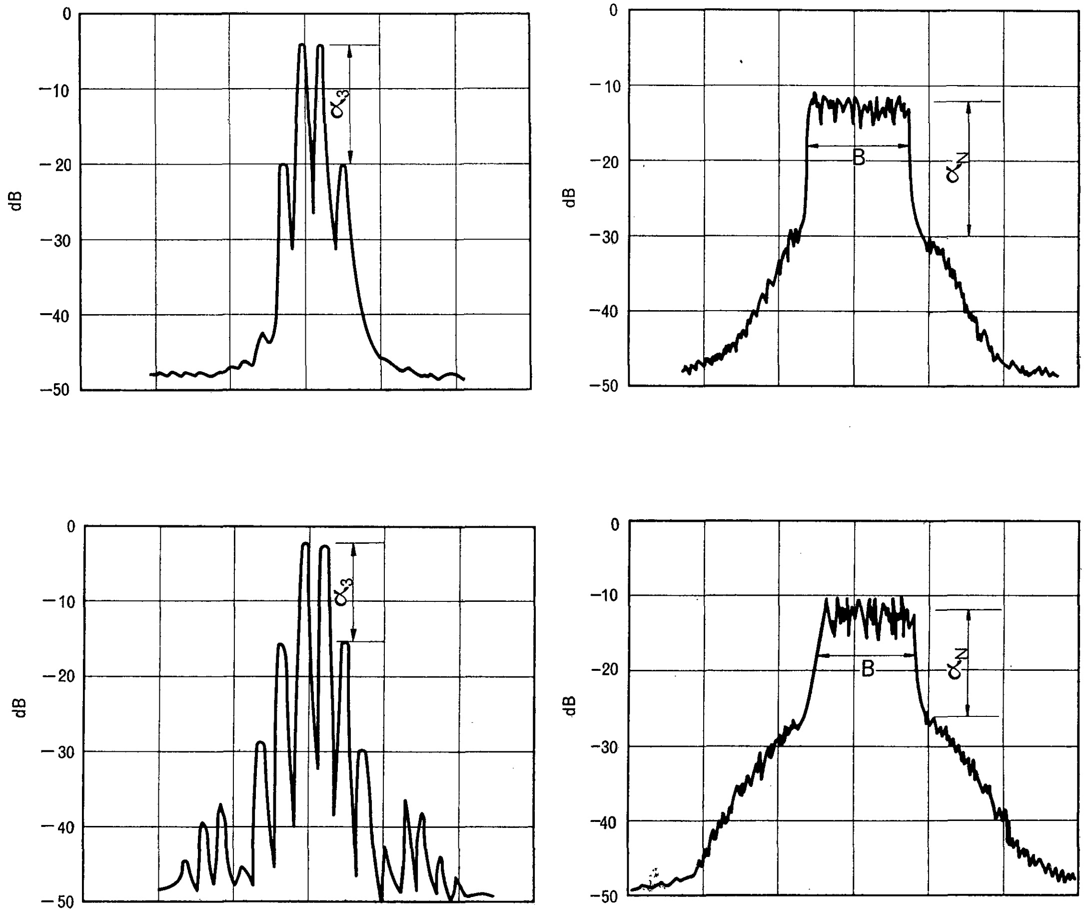


FIGURE 4

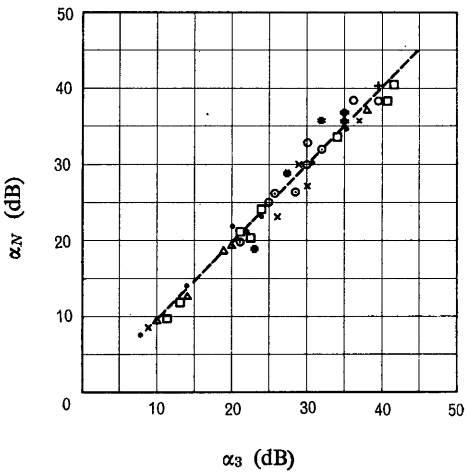


FIGURE 5

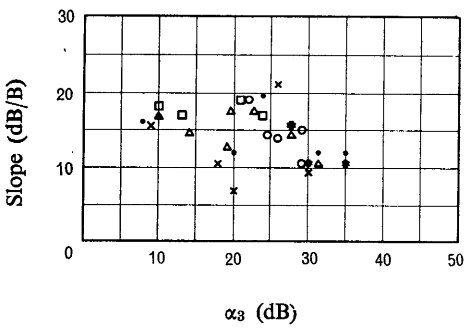


FIGURE 6

REPORT 326 *

DESIGN OF HF TRANSMITTERS AND THEIR OUTPUT COUPLING NETWORKS TO REDUCE SPURIOUS RADIATIONS

(Study Programme 7A/I)

(1966)

1. Introduction

Output circuits of most transmitters operating in the high-frequency band are based upon the classical Π – Γ configuration consisting of a Π network followed by an inverted–Γ section. This arrangement provides effective tuning and impedance transformation. Elaboration of the basic circuit is often necessary, because the physical size of components used in high power circuits can result in circuit configurations having undesirable responses which are prone to support unwanted oscillations.

In considering the transmitter performance that is achievable using the best modern techniques in design and construction, the three types of unwanted radiation most liable to be troublesome can be considered in turn.

2. Harmonic radiation

Harmonics generated in drive equipment are not usually a problem in conventional transmitters due to the suppression provided by the tuned amplifier stages. Where, however, a major proportion of the amplification is provided by wideband amplifiers, the performance of the drive equipment must be adequate to satisfy the overall equipment performance requirements.

The major cause of harmonic radiations from transmitters is the waveform distortion in radio-frequency power amplifiers. Also it frequently happens that the anode and output circuits can combine to produce a resonant condition at a harmonic frequency, and if this occurs the harmonic can be accentuated to an unacceptable level. The elimination or the suppression of such resonances is one of the major design considerations, as alterations in equipment layout tend to shift the frequency at which resonance occurs rather than remove it unless resistance absorbers in some form are used.

Care in design and equipment layout is necessary to avoid potentially troublesome circuit resonances at harmonic frequency, which can occur if the reactance of the anode tuning capacitor, in association with its connections, becomes inductive and resonates with the reactance of the valve output capacitance. Equal and opposite reactances can also occur in output coupling and matching networks and form a high impedance circuit at the harmonic frequency, which is then poorly attenuated.

In general with attention to circuit layout in initial design, harmonics within the HF band can be reduced to about 60 dB relative to the wanted emission, using simple Π – Γ anode output circuits, but in high-power transmitters the addition of tuned filters may be

* This Report was adopted unanimously.

necessary to reduce some harmonics to less than the present maximum permitted level of 50 mW.

Especially with short wave transmitters, the influence of mismatch at the harmonic frequencies on the attenuation of these filters should be taken into account.

The design of such filters should be based on a standing wave ratio of at least 10 for the harmonics (see Doc. I/46, 1963–1966).

Although the limits for spurious radiation given in Recommendation 329–1 are adequate for the protection of receivers at large distances from the transmitter, they may not be sufficiently low to avoid interference to other local services (e. g. television and mobile services). Spurious radiation outside the high-frequency band can be dealt with in several ways. Low-pass filters may be fitted at the output of the transmitter to attenuate all harmonics above about 40 MHz (see Doc. I/9, 1963–1966). By this means additional suppression up to 30 dB is achievable at reasonable cost. Account should be taken of the possible influence on the necessary values of transmitter tuning parameters caused by inserting such filters (see Doc. I/45, 1963–1966). In special cases a further suppression of harmonics at discrete frequencies may be necessary. This may be achieved by the use of resonant $\lambda/4$ open-circuit transmission lines in either coaxial or parallel-twin form (see Doc. I/3, 1963–1966).

In multi-transmitter installations which use a common antenna, or closely-coupled antennae, there is the possibility of intermodulation components being generated. In some cases effective reduction of these components is possible by using additional band-pass filtering in the output of each transmitter (see Doc. I/8, 1963–1966).

3. Parasitic radiation

The frequencies of parasitic oscillations are essentially unrelated to those of the input signals to the transmitter. No general rules on the methods of suppressing these oscillations can be given, because parasitic oscillations bear no relation to the normal operation of the circuit, and each case has to be treated on its merits. There are, however, three major causes of such oscillations:

- ineffective screening between high- and low-level circuits;
- insufficient care in wiring between different sections of the transmitter. As far as possible all cabling and control wiring should be kept out of compartments in which radio-frequency circuits are mounted and all leads entering the radio-frequency compartments should be filtered;
- circuits introduced to cancel an oscillation at one frequency may produce a positive feedback path at some other frequency, generally higher than the fundamental, e. g. neutralizing circuits in grounded cathode amplifiers.

In general, push-pull circuits are more prone to this type of oscillation, because there are more paths inherent in the circuits.

4. Other unwanted radiation

Other spurious radiation can arise from a number of causes and generally comprise unwanted components which bear no harmonic relationship to the carrier or modulation frequencies. Those bearing a relationship to the carrier are produced in the frequency-determining circuits of the transmitter particularly in modulators and frequency synthesisers. They are not produced in final-frequency amplifier stages and they can be either in or out of band. Those bearing a relationship to the modulating frequencies are inter-modulation products and are caused by non-linearity in amplifier stages.

In some transmitters the radiated signal (F_r) is produced by modulating an oscillation at a conversion frequency (F_a) with the signal carrying the intelligence at a sub-carrier frequency (F_b). The modulating process produces a number of components of the form $pF_a \pm qF_b$, p and q being integers. The wanted signal is the component for which $p = q = 1$. The modulator must be designed so that the levels of higher order components are kept to low values.

A case of particular difficulty occurs when

$$F_r = \pm F_b \left(\frac{p-q}{p-1}\right)$$

in practice usually when F_r is a multiple of F_b, since the unwanted component cannot be removed by tuning the modulator. However, by carefully selecting the levels at which the modulator operates, the unwanted component can be reduced to 60 dB below the level of the wanted component. The production of even-order components is largely avoided by using a balanced modulator. Sufficient selectivity should follow the modulator to avoid the formation of intermodulation products at the grid of the following amplifier.

5. Screening and earthing

Because all transmitters generate harmonic and other unwanted frequencies, an efficient screening enclosure (comprising walls, floor and roof) is necessary to minimize their radiation. The presence of exterior circulating radio-frequency currents in members and panels forming the enclosure must be avoided and good electrical contact between all parts is essential. The use of closely-spaced bridging contacts is advisable for all removable panels and doors and also wedge-action catches are preferred.

Openings and slots in transmitter enclosures can radiate strongly and in a highly directional manner at frequencies for which they are resonant. This can be avoided by placing a suitable screen behind the opening.

Conductors carrying power supplies to the transmitter and also control and other cables connected to remote equipment may need to be screened and have filters inserted where they pass through the walls of the enclosure. Filters provided in radio-frequency output feeders should be individually screened and mounted in the wall of the screening enclosure.

Efficient earthing of the transmitter framework and enclosure is desirable to minimise radiation due to the existence of unavoidable radio-frequency currents in the transmitter enclosure and in any case is essential for the safety of personnel. Where balanced output feeders are employed, earth currents should be minimized by paying attention to the symmetry of the feeder system. The design of coaxial output feeder terminations should be such as to avoid the production of voltages on the outer surface of the feeder. Where changes from the unbalanced to the balanced mode of operation occur, the balance point of the transformer or other device used should be connected to an efficient low-reactance earth.

It is common practice to make radio-frequency connections between units within the transmitter by coaxial cables. These cables should be terminated as directly as possible at the generator and load terminals of the equipment, to avoid the introduction of undesirable paths (via frameworks, etc.), which can become efficient resonators at harmonic frequencies and often contribute to severe degradation in crosstalk performance of coaxial cables.

6. Effect of contacts having non-linear characteristics

Although not strictly a question of transmitter design, the possibility of unwanted harmonics and intermodulation components by the excitation of conductors containing non-linear contacts in antennae and elsewhere in the vicinity of the transmitters should not be overlooked (see Doc. I/3, 1963–1966). It is shown that, in at least one case of a multi-transmitter installation, the level of spurious radiation can increase by up to 30 dB due to this cause (see Doc. I/8, 1963–1966). Careful attention to the bonding of all joints in metallic structures and antennae is the only way to avoid this undesirable effect.

7. Conclusions

The levels of spurious radiations from transmitters are largely controlled by features of transmitter output coupling network design and generally can be reduced to the extent required by the Radio Regulations for new high-power HF transmitters. However, additional suppression is frequently necessary, to avoid interference to other services operating outside the HF band.

Other unwanted radiation in the HF band can also arise from the frequency generation and frequency conversion equipment and also from intermodulation products caused by non-linearity of amplifier stages and of conductors external to the transmitter. These spurious radiations can be kept to low values only by taking account of the design factors involved, a number of which have been referred to above.

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STUDY GROUP I

(Transmitters)

Terms of reference:

1. Study and presentation of proposals on questions relating to radio transmitters and to the characteristics of radio emissions; in general, the coordination of all proposals concerning the rational and economical use of the radio-frequency spectrum from the point of view of radio emissions.
2. Study of unwanted radiations from electrical apparatus and installations and the interference caused to radiocommunications by these radiations.

Chairman: Mr J. LOCHARD (France)
Vice-Chairman: Professor S. RYŻKO (P. R. of Poland)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP I

1. Spectra and bandwidths of emissions

Study Programme 5A/I, Recommendation 328-1, Reports 178-1, 179 and 325.

The bandwidth recognized in the Radio Regulations, Geneva, 1959 (in particular Nos. 89 to 91 and Appendix 5), is simply a parameter determined by an arbitrary convention applied to the power spectrum of an emission, and knowledge of the entire spectrum is necessary to assess interference and to determine the frequency spacing required between radio channels.

Recommendation 328-1 specifies the limits which can be imposed on the spectra of the most usual classes of emission, with a view to economizing radio-frequency bands by reducing mutual interference between neighbouring radiocommunications.

In 1966, the provisions in this Recommendation, which relate to Class A3 and Class A3B radiotelephone emissions, were drawn up on the basis of measurements conducted with narrow-band filters on transmitters modulated by white noise. This modulating signal reproduces fairly satisfactorily the statistical properties of an actual audio signal, which itself would be very difficult to measure.

Report 325 describes the conditions in which the measurements were carried out and compares the results obtained in various cases when the limits prescribed in the Recommendation were observed.

Report 179 shows how the limits in Recommendation 328-1 can be applied and checked with respect to various Class A1 and F1 radiotelegraph emissions.

Report 178-1 gives the principal results that can be deduced from the practical application of different theories to power spectra and to the measurement and limitation there of.

Study Programme 5A/I lists the numerous studies which have still to be carried out to complete the Recommendation and improve its provisions; some theoretical points of departure for these studies are mentioned in Report 178-1. This Study Programme was brought up to date and simplified in 1966.

2. Measurement of spectra and bandwidths

Study Programme 6A/I, Recommendation 327-1, Reports 178-1 and 324.

The measurement of spectra and bandwidths, which is required before the limits referred to above can be applied and for the assessment of interference, is always difficult, particularly for the theoretical reasons set forth in Report 178-1.

Recommendation 327–1 describes the various methods that can be used and the characteristics and accuracies obtainable with different types of measuring apparatus. Several points in this Recommendation were revised in 1966.

The measuring methods described in Recommendation 327–1 become impracticable when the degree of noise and interference near the frequency band occupied by the emission is no longer negligible; this is always the case when monitoring stations are far from the transmitter. Report 324, prepared in 1966, describes two methods of arriving at an approximate bandwidth estimate which may be applied in such cases.

Study Programme 6A/I, revised in 1966, lists the most important studies required to improve measuring methods.

3. Spurious radiation

Study Programme 7A/I, Recommendation 329–1 and Report 326.

Appendix 4 to the Radio Regulations, Geneva, 1959, specifies the limits for spurious radiation in respect of emissions the fundamental frequencies of which are below 235 MHz.

Recommendation 329–1, revised in 1966, specifies possible limits for emissions between 235 and 960 MHz and describes the appropriate measuring procedures.

Report 326, drawn up in 1966, describes the methods to be used to reduce spurious radiation by HF transmitters.

Study Programme 7A/I mentions the studies that still have to be made in this field.

4. Compression of the spectra of radiotelephone and radiotelegraph signals in the HF bands

Questions 2/I and 3/I and Reports 176–1 and 177.

While it is possible to limit spectra and reduce spurious radiation by linear filtering operations, " compression " of spectrum width can only be achieved by more complex non-linear operations.

Reports 176–1 and 177 describe the systems already developed and explain why the propagation conditions encountered in HF bands make them difficult to apply. Report 176–1, as revised in 1966, however, refers to a method of compressing the dynamics of a radiotelephone signal by which some saving of the spectrum has been secured in the HF bands.

5. Limitation of unwanted radiation from electrical apparatus and installations

Question 4/I, Study Programmes 4A/I, 4B/I and 4C/I, Opinion 2, Recommendation 433, Reports 182 and 323.

To limit the interference caused to radiocommunications by electrical installations, it is necessary to introduce national regulations with which the manufacturers and users of electrical apparatus must comply. The C.C.I.R. therefore decided to examine the technical bases of such regulations in collaboration with the International Special Committee on Radio Interference (C.I.S.P.R.), and organs of the International Electrotechnical Commission.

The above-mentionned texts explain in detail the studies required as well as the provisions governing such collaboration, and describe the results obtained so far. Administrations are invited in Recommendation 433 to consider C.I.S.P.R. publications of 1961 and 1964 and to apply the methods examined by that organization.

Report 323 gives references to the regulations to be followed in reducing such interference so far as ships' electrical equipment is concerned.

6. Stabilization of the frequency and frequency tolerances of transmitters

Study Programmes 8A/I and 9A/I and Reports 180–1 and 181–1.

For most classes of station, frequency tolerances are laid down in Appendix 3 to the Radio Regulations, Geneva, 1959.

Report 181–1 indicates how far it is desirable and possible to restrict these tolerances in future in accordance with Study Programme 9A/I.

Report 180–1 summarizes the practical results obtained with different stabilization procedures.

Both Reports were revised and extended to cover other cases in 1966.

Study Programmes 8A/I and 9A/I describe the studies to be made in this field.

7. Power of radio transmitters

Recommendation 326–1.

The main purpose of Recommendation 326–1, revised in 1966, is to unify methods of determining the different powers of radio transmitters defined in the Radio Regulations, Geneva, 1959 (Nos. 94, 95, 96 and 97) and to give the relationships between these values, which in many cases depend upon the signal emitted, permissible distortion and the method of measurement. The Recommendation therefore attempts to standardize these factors.

8. Classification and designation of emissions

Question 1/I, Recommendations 325 and 432 and Opinion 1.

Recommendation 325 gives difinitions which were requested by the Administrative Radio Conference, Geneva, 1959.

Recommendation 432 proposes a new method of designating emissions which is intended to meet the requirements of Administrations and the IFRB in establishing the Frequency List and the International Master Frequency Register, since it is impossible to designate the more recent classes of emission without ambiguity according to the method now prescribed in Article 2 of the Radio Regulations, Geneva, 1959.

Opinion 1 indicates the procedure to be followed in disseminating and acting upon the comments made by Administrations after they have tested the new method.

QUESTION 1/I *

CLASSIFICATION OF EMISSIONS

(Recommendation No. 8 of the Administrative Radio Conference, Geneva, 1959)

The Administrative Radio Conference, Geneva, 1959

CONSIDERING

(a) that Article 2, Section I, of the Radio Regulations, Geneva, 1959, classifies emissions for the purpose of designation;

(b) that certain symbols are used for classes of emission which are not precisely specified;

(c) that it may be necessary to specify new classes of emissions in the future;

(d) that, in the recording processes used by the International Frequency Registration Board and by certain Administrations, particularly in mechanical recording processes, a simple and precise method of designation is required, using the smallest practicable number of symbols for each designation to provide all the essential information;

(e) that it may be useful to combine, in a single series of symbols, the information now classified as supplementary characteristics with that giving the type of modulation of the main carrier;

(f) that the present method of classifying emissions does not adequately provide for systems employing multiple modulation processes;

(g) that the increasing use of multi-channel telephone and telegraph systems makes it desirable to classify them in categories and to adopt a uniform designation for the channels of such systems;

(h) that pulse-modulation is not intrinsically a basic modulation process, but is a form of signal stimulus which gives rise to amplitude-, frequency- or phase-modulation or a combination of these modulations;

(i) that the Board sometimes receives or requires from Administrations additional significant information of a supplementary nature—e. g., carrier level and telegraph signal code information, which is not always provided for in the present system of designation;

(j) that the present system of designation does not enable all emissions to be specified precisely or completely;

(k) that the terms emission, radiation and transmission are not defined in the Radio Regulation, Geneva, 1959, and that they are liable to confusion, not only when they are translated from one language to another, but also when they are used in the same language;

RECOMMENDS THAT THE C.C.I.R.

1. consider, in conjunction with the Board, all emissions and characteristics requiring classification;

2. study, in conjunction with the Board, various methods of designating and classifying emissions, and develop a method which could be used over a long period and which would enable all the essential information to be provided;

* Formerly, Question 207(I).

3. report their conclusions on these matters, and make a Recommendation, in time for a decision to be taken at the next Administrative Radio Conference;

4. define the terms emission, radiation and transmission so that they may be used consistently and without confusion and be readily translated from one working language to another.*

OPINION 1-1

CLASSIFICATION AND DESIGNATION OF EMISSIONS

(Recommendation 432)

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that studies of the contributions related to Question 207, from Administrations and the I.F.R.B. have been made;

(b) that as a result of this study, Report 175, Geneva, 1963, has been established proposing a new method for the classification and designation of emissions;

(c) that partial trials have been conducted by several Administrations and the I.F.R.B. to ascertain the effectiveness of the new method proposed;

(d) that as a result of these partial trials, it has been possible to introduce improvements into the method which is described in Recommendation 432;

IS UNANIMOUSLY OF THE OPINION that

1. Administrations should be invited to send their comments on the results of the application of Recommendation 432 to the Director, C.C.I.R., who will transmit them to the Chairman, International Working Party I/1.

2. the Chairman, International Working Party I/1 should be invited to collect the comments received and to circulate them to the Party for study, and to present the results of its work to the next meeting of Study Group I.

QUESTION 2/I **

COMPRESSION OF THE RADIOTELEPHONE SIGNAL SPECTRUM IN THE HF BANDS

(1961)

THE INTERNATIONAL FREQUENCY REGISTRATION BOARD,

IN VIEW OF

the request of the PANEL OF EXPERTS in Section II of Part D of its Interim Report, after considering:

(a) the congestion in the bands between 4 and 27·5 MHz;

(b) the need to adopt new methods for the solution of the frequency problems with which Administrations are confronted in the use of those bands;

* In collaboration with Study Group XIV.

** Formerly, Question 219(I).

(c) the work accomplished in the field of communication theory;

(d) the need to know what practical experience has been acquired in the matter of compressing the spectrum occupied by HF radiotelephone signals for the Panel's second session;

AND IN VIEW OF

No. 180 of the International Telecommunication Convention, Geneva, 1959;

DECIDES

to submit the following urgent question to the C.C.I.R.:

1. what, in practice, can be done to reduce the spectrum space occupied by HF radiotelephone signals;

2. what experience has been acquired in so doing, for example, what degradation of intelligibility or ability to converse accompanies the use of spectrum-reducing techniques?

QUESTION 3/I *

COMPRESSION OF THE RADIOTELEGRAPH SIGNAL SPECTRUM IN THE HF BANDS

(1961)

THE INTERNATIONAL FREQUENCY REGISTRATION BOARD,

IN VIEW OF

the request of the PANEL OF EXPERTS in Section II of Part D of its Interim Report, after considering;

(a) the congestion in the bands between 4 and 27·5 MHz;

(b) the need to adopt new methods for the solution of the frequency problems with which Administrations are confronted in the use of those bands;

(c) the work accomplished in the field of communication theory;

(d) the need to know what practical experience has been acquired in the matter of compressing the time-bandwidth product of HF radiotelegraph (or other digital) signals for the Panel's second session;

AND IN VIEW OF

No. 180 of the International Telecommunication Convention, Geneva, 1959;

DECIDES

to submit the following urgent question to the C.C.I.R.:

* Formerly, Question 220(I).

what are the advantages, limitations and practical experience with:

1. phase-change signalling systems;
2. digital signalling systems which employ three or more states of amplitude, frequency-shift or phase change;
3. coding techniques which provide either message compression or error reduction, or both?

QUESTION 4/I *

LIMITATION OF UNWANTED RADIATION FROM ELECTRICAL APPARATUS AND INSTALLATIONS

The C.C.I.R., (1953 - 1963)

CONSIDERING

(a) that Resolution No. 5, annexed to the International Telecommunication Convention, Buenos Aires, 1952, required the study of the influence of intentional or parasitic oscillations on radio services, especially broadcasting and mobile services, with a view to the possible establishment of standards permitting a harmonious co-existence of radio services with industrial installations producing radio oscillations;

(b) that the harmonious co-existence of radio services with industrial installations, producing radio oscillations, involves close collaboration between organizations representing the manufacturers and users of these installations on the one hand, and the radio services on the other, for which the existing collaboration between the C.C.I.R. and the Special International Committee on Radio Interference (C.I.S.P.R.) provides;

(c) that the C.I.S.P.R. has already studied extensively, and continues to study, the permissible signal-to-interference ratios for sound and television broadcasting, but has not yet made equivalent studies for other radio services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what is the maximum level of interference, caused by radiation from electrical apparatus and installations, that can be tolerated in various frequency ranges by the types of equipment employed by radio services, especially by the mobile services;
2. what are the most appropriate means of determining the level of intentional or parasitic radiations produced by electrical apparatus and installations;
3. to what levels is it practicable to reduce such radiations?

Note 1. – Some examples of electrical equipment liable to cause disturbance are given in Opinion 2; radio transmitters are excluded.

Note 2. – In this study, the C.C.I.R. should, to avoid duplication of work, keep itself informed of the results of the studies of the C.I.S.P.R. on the same subject.

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* Formerly, Question 227(I).

STUDY PROGRAMME 4A/I *

LIMITATION OF UNWANTED RADIATION FROM ELECTRICAL APPARATUS AND INSTALLATIONS

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

CONSIDERING

(a) that the interfering effect of interference is dependent not only on the level of the unwanted radiation, but also on its shape and on the nature of the service which is suffering the interference;

(b) that it is desirable to compare measurements made at various test sites and using different methods;

(c) that the effect of interference depends on the amount of coupling between the source of unwanted radiation and the affected receiver;

(d) that the C.I.S.P.R. has already extensively studied, and continues to study, the measuring methods for measuring the level of radiation arising from electrical apparatus and installations affecting sound and television broadcasting receivers;

(e) that due regard should be given to the special requirements of radiocommunication services other than broadcasting;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of which parameters of the interfering field should be measured, taking into account the polarization and the relation between the magnetic and electric field of the unwanted radiation;
2. the effects of the relative positions of the electrical apparatus and installations, and the measuring set, the number of measurements at different distances and the directions in which measurements should be made;
3. the effect on the measured field of the characteristics of different open sites;
4. the methods to be used to measure the radiation from electrical apparatus and installations which are situated indoors and the relationship between measurements made indoors and those made on open sites;
5. the evaluation of interference due to the presence of radio-frequency voltages in the mains leads of the electrical apparatus and installations, including the methods of measurement to be used;
6. the effect of the working conditions of the disturbing apparatus on the results of these measurements;
7. to ascertain the appropriate antennae to be used for measurements in the different frequency bands;
8. the characteristics of the measuring instruments to be used for the measurements, particularly the bandwidths;
9. the dependence of the interference with various radio services upon the shape, as a function of time, of the unwanted radiation;
10. the statistical distribution and the representative values for the amount of coupling between the interference sources and the receiving antennae in the services affected;

* This Study Programme replaces Study Programme 227A.

11. determination of the amount of coupling between the antenna of a ship's receiver and the electrical equipment aboard, taking into account the limits recommended by the International Electrotechnical Commission (I.E.C.), in its Publication 92–1, for the interfering voltage at the ship's electrical equipment terminals.

Note. – In this study the C.C.I.R. should, to avoid duplication of work, keep itself informed of the results of the studies of the C.I.S.P.R. on the same subject.

STUDY PROGRAMME 4B/I *

EXAMINATION OF RESULTS OBTAINED BY THE INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

The C.C.I.R., (1963 – 1966)

CONSIDERING

(a) that, since its last Plenary Assembly in Stockholm (1964), the International Special Committee on Radio Interference (C.I.S.P.R.) has forwarded to the C.C.I.R., the documents containing the provisions it has so far approved;

(b) that these documents now constitute a considerable, consistent whole, which should form a basis for studies leading to the preparation of national and international regulations;

(c) that there is a need to establish relationships between the results of measurements using C.I.S.P.R. methods and the values of noise power used by C.C.I.R., for example in Report 322;

(d) that it is for Administrations to carry out such studies;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. to make measurements, using the methods and equipment described in C.I.S.P.R. and I.E.C. Publications (see [1] to [4]) in the neighbourhood of sources of radio interference and to determine cases in which the interfering apparatus does or does not satisfy the limits indicated in the C.I.S.P.R. Publications (see [5] to [7]);

2. to make measurements in the vicinity of radio-receiving installations suffering from interference and to determine the sources of disturbance and their characteristics;

3. to determine cases in which the measurement method and limitations studied by C.I.S.P.R. are satisfactory and those in which they are not;

4. to examine the action to be taken to extend and improve the measurement methods and limitations studied by C.I.S.P.R. whenever they are not satisfactory;

5. to make measurements of the mean noise power of interference and to compare the results with the corresponding data from C.I.S.P.R.–type instruments.

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* This Study Programme replaces Study Programme 227B.

BIBLIOGRAPHY

1. C.I.S.P.R. Publication 1 (1961). *Specification of apparatus for measuring radio interference in the range from 0.15 to 30 Mc/s*, with its: Supplement No. 1 (1966) Publication 1A, Measurements on high-voltage transmission systems; Supplement No. 2 (1966) Publication 1B, Measurements on industrial, scientific and medical radio-frequency equipments.

2. C.I.S.R.P. Publication 2 (1961). *Specification of apparatus for measuring radio interference in the range from 25 to 300 Mc/s*, with its: Supplement No. 1 (1966) Publication 2A, Measurements on industrial, scientific and medical radio frequency equipment.

3. I.E.C. Publication 106 (1959). *Recommended methods of measurement of radiation from receivers for amplitude-modulation, frequency-modulation and television broadcast transmissions.*

4. I.E.C. Publication 106A (1962). *Measurement of radiation at the intermediate frequency and its harmonics in the range 30 to 300 Mc/s.* Extension of the general methods of measurements of radiation in the range 300 to 1000 MHz.

5. C.I.S.P.R. Publication 7 (1966). *Recommendation of the C.I.S.P.R.* relating to limits of interference from industrial scientific and medical radio-frequency equipment, ignition systems, sound and television broadcast receivers, electric motors, relating to compliance with limits for appliances in large scale production, relating to limits for the mains interference ratio of long and medium wave radio receivers, etc.

6. C.I.S.P.R. Publication 8 (1966). *Reports and Study Questions of the C.I.S.P.R.*

7. C.I.S.P.R. Publication 9 (1966). *C.I.S.P.R. limits of radio interference and report of national limits.*

(All these publications are sold by the I.E.C., Geneva)

STUDY PROGRAMME 4C/I *

PROTECTION OF RADIOCOMMUNICATION EQUIPMENT FROM INTERFERENCE BY ELECTRICAL APPARATUS AND INSTALLATIONS

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

CONSIDERING

(a) that the International Special Committee on Radio Interference (C.I.S.P.R.) is studying the means for protecting radiocommunication services from interference by electrical apparatus and installations;

(b) that, to proceed with its studies, the C.I.S.P.R. has asked the C.C.I.R. to state the minimum field-strength to be protected for each service;

(c) that certain information is available from the work of certain Study Groups, notably II, III, VI, VI, X, XI, XII and XIII;

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* This Study Programme replaces Study Programme 227C.

(d) that it is a matter of urgency for the C.C.I.R. to define the minimum fields to be protected, together with necessary protection ratios, for each service and each type of interference;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. to examine the relevant conclusions of Study Groups II, III, IV, VI, X, XI, XII and XIII concerning signal-to-noise ratios, signal-to-interference ratios, minimum field strengths required and levels of natural noise, reached at the XIth Plenary Assembly;
2. to collect and present in a suitable form the values of the minimum field to be protected and the tolerable protection ratio for each service and type of interference, insofar as the necessary information is available;
3. to specify the way in which the field and interference should be measured in each case.

Note. – The C.C.I.R. will continue to supply information on this subject to the C.I.S.P.R. as it becomes available.

OPINION 2

COOPERATION WITH THE INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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

CONSIDERING

(a) that cooperation between the International Special Committee on Radio Interference (C.I.S.P.R.), and the C.C.I.R. is desirable;

(b) that cooperation between the C.I.S.P.R. and the C.C.I.R. has been of value;

IS UNANIMOUSLY OF THE OPINION

that the C.I.S.P.R. should be invited to continue cooperation with the C.C.I.R. on the following subjects:

1. study of methods of measurement and procedures (in some cases issued by the International Electrotechnical Commission), for limiting undesirable radiations produced by:

1.1 electrical apparatus and installations (Question 4/I; Study Programme 4A/I);

1.2 all types of receivers (Recommendation 239-1; Question 6/II; Publications 106 and 106A of the International Electrotechnical Commission);

2. determination of the maximum interference level tolerable in complete systems (Question 4/I);
3. identification of sources of interference with radio reception (Question 15/VIII);
4. study of the usable sensitivity of receivers in the presence of quasi-impulsive interference (Queston 2/II);
5. study of the relationships between various parameters of man-made noise; in particular between the quasi-peak voltage, the mean noise power and the amplitude-distribution law (Study Programme 21A/VI).

STUDY PROGRAMME 5A/I *

SPECTRA AND BANDWIDTHS OF EMISSIONS

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

CONSIDERING

(a) that, from the point of view of economy in the radio-frequency spectrum and interference to neighbouring radio channels, it is desirable that the emitted power spectrum in its outer parts contains as small a power, and exhibits as steep a slope as practicable;

(b) that, without impairing the transmission of information at the rate and with the quality required, a reduction of power in the outer parts of the spectrum and an increase of its slope might be achieved by improving transmitters of conventional design or by introducing new principles based on appropriate methods of filtering and coding of the signals to be transmitted;

(c) that Appendix 5 to the Radio Regulations, Geneva, 1959, and Recommendation 328-1, deal with only a limited number of classes of emission and further do not always take account of conditions encountered in actual traffic;

(d) that the definitions of occupied bandwidth and of necessary bandwidth, in the Radio Regulations, Geneva, 1959, are not perhaps suitable for all classes of emission, in particular for those involving frequency-division multiplex, with more than one hundred channels;

(e) that it is, therefore, necessary to extend the theoretical and experimental study of spectra for the various classes of emission;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. re-examination of Appendix 5 to the Radio Regulations, Geneva, 1959, and of Recommendation 328–1;

2. theoretical studies on the spectra of emissions, the results of which should be compared with those obtained by experimental studies mentioned in § 3;

3. measurement of spectra of the various classes of emission in general use, under actual or simulated traffic conditions, in accordance with the following provisions:

3.1 the measurements should be made using the methods set out in Recommendation 327–1 and in accordance with the provisions of Study Programme 6A/I;

3.2 the studies should be carried out with a view to determining the relationship between the radiation outside the necessary band and

3.2.1 the shaping of the modulating signal;

3.2.2 the non-linear distortion in the transmitter;

3.3 various classes of emission should be considered in conjunction with different types of transmitters, mainly in the frequency range 10 kHz—30 000 kHz, as follows:

3.3.1 Telegraphy emissions

A1, A2 Automatic morse;

F1, F6 Teleprinter and other automatic telegraph equipment with or without error-correction systems, working at various modulation rates between 50 and 300 bauds and with frequency shifts up to 500 Hz;

* This Study Programme, which replaces Study Programme 181, does not arise from any Question under study.

A7A, A7B Various frequency-division multiplex systems in common use, using channels spaced at 120 Hz, 170 Hz, or multiples thereof and used in conjunction with equipment as above for F1, F6.

3.3.2 Telephony emissions

A3, A3A, A3B, A3H, A3J Speech channels of commercial and broadcast quality (as appropriate) with or without privacy equipment. The possibilities of using simulated speech signals for carrying out the measurements should be explored.

F3 Single-channel emissions.

3.3.3 Facsimile emissions

A4A

F4

3.3.4 Other emissions

A3, F3 Multi-channel emissions in the VHF (metric), UHF (decimetric) and SHF (centimetric) bands;

3.4 in connection with § 3.2.1, the principles discussed in Report 178–1 should be examined with a view to their possible application to new equipment;

3.5 in connection with § 3.2.2, the relationship should be studied, in amplitude-modulated transmitters, between the level of spectrum components near the limits of the occupied band and the intermodulation distortion produced by the transmitters. Methods of measuring and specifying the acceptable limits for intermodulation distortion of transmitters should be sought for various classes of amplitude-modulated emissions;

3.6 theoretical and experimental studies of emissions should be continued, with a view to making meaningful measurements of occupied bandwidth in practical situations such as in the presence of noise or interference;

3.7 the studies of the concepts of necessary and occupied bandwidth should be continued, with a view to achieving improved definitions and methods of measurement, particularly for the emissions classified in § 3.3.4;

4. to determine to what extent the radiation outside the necessary band can be reduced for transmitters now in use, and whether a stricter limitation could be imposed on transmitters installed in the future, with a view to the eventual proposal to an Administrative Radio Conference of:

- the limits to be imposed on the spectra of emissions from existing transmitters;
- the limits to be imposed on the spectra of emissions from future transmitters.

STUDY PROGRAMME 6A/I *

METHODS OF MEASURING SPECTRA OF EMISSIONS IN ACTUAL TRAFFIC

The C.C.I.R., (1953 – 1963 – 1966)

CONSIDERING

(a) that it is of the highest importance to be able to determine with accuracy the bandwidths occupied and the spectra of emissions in actual traffic;

(b) that the documentary material, at present available, does not give a full idea of the value of the results obtained in actual traffic with the apparatus used for measuring the spectrum of a periodic signal;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. for a given type of measuring equipment, comparison of the results obtained on periodic signals and on actual traffic signals of comparable characteristics and of the same modulation rate;
2. comparison of the results obtained with different methods, such as those described in Recommendation 327–1;
3. continuation of experimental and mathematical studies in an attempt to explain the physical meaning of the results obtained in actual traffic, taking account of the various forms of energy distribution within the spectrum, especially those resulting from the use of privacy systems;
4. determination of the degree of accuracy obtainable with different methods, such as those described in Recommendation 327–1;
5. development of practical measuring methods, preferably employing existing equipment, to be used by monitoring stations.

STUDY PROGRAMME 7A/I **

SPURIOUS RADIATION (OF A RADIO EMISSION)

The C.C.I.R., (1951 – 1959 – 1963)

CONSIDERING

(a) that, for wave propagation at frequencies where ionospheric reflection plays an important part, the spurious radiation of an emission may be propagated differently, in any given direction, from the fundamental emission in the same direction due to the wide difference in

* This Study Programme, which replaces Study Programme 180, does not arise from any Question under study.

** This Study Programme, formerly Study Programme 182(I), does not arise from any Question under study.

frequencies; this effect is additional to that caused by the difference in antenna directivity for the emission and the spurious radiation;

(b) that the spurious radiation of a transmitter provided for one service may interfere with other services in other parts of the frequency spectrum;

(c) that the relationships between the fundamental emission and harmonic field intensities, and between the radiated powers and field intensities of harmonics and other spurious radiation measured at a distance from the transmitter, differ markedly where:

- both the fundamental emission and the spurious radiation involve ionospheric propagation;
- only the spurious radiation involves ionospheric propagation;
- only the fundamental emission involves ionospheric propagation;
- neither the fundamental emission nor the spurious radiation involves ionospheric propagation;

(d) that, to achieve or maintain a good standard of practice for transmitters, with respect to the suppression of spurious radiation, it is essential to have readily applicable methods of specifying and testing equipment;

(e) that, since many existing high power transmitters have a fundamental-to-harmonic power ratio of 70 dB or greater, it is desirable to consider further:

- the need to revise the limits for harmonic power output in such cases;
- the reduction of harmonic radiation from conductors, with non-linear characteristics located within the high intensity fundamental field of the transmitter, which might act as subsidiary generators;

(f) that different relationships exist between the signal-to-noise ratios and the interference caused by spurious radiations for different services in the various frequency bands. For example, in view of the susceptibility of television to interference, the particular spurious radiations falling within channels, which are in use by television receivers in the vicinity of the interfering station, are of paramount importance. The attenuation of those particular spurious radiations may, in some cases, need to be substantially greater than limits which may be applicable for some other services. Other services may also have special requirements peculiar to their own needs;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. Appendix 4 of the Radio Regulations, Geneva, 1959, and Recommendation 329–1, should be re-evaluated, for which purpose the various Administrations should submit data on measurements of power in the antenna and field intensity of spurious radiations, to enable a more definite evaluation to be made of the relationships between them. Such evaluation should take into account the signal-to-noise ratio aspects as related to the different services with regard to the interference problem;

2. secure further data on the methods of measurement of spurious radiations, in particular, on the measurement of such radiations produced as a result of modulation, under conditions in which the results obtained depend on the bandwidth, the integration time and other characteristics of the measuring equipment;

3. the design of antennae and antennae feeders useful in reducing spurious radiations;

4. the design of transmitters and their output coupling networks, with the object of reducing spurious radiations;

5. determination of the special conditions which may apply to high power transmitters. In this connection, consideration should be given to radiation from conductors with non-linear characteristics which such transmitters may excite;

6. the particular case of stations, comprising several transmitters working on neighbouring frequencies and feeding adjacent tightly coupled antennae, or a common antenna; examine the mechanism of the production of spurious radiation by intermodulation between the different emissions; determine methods for reducing these spurious radiations, in particular by the insertion of filters with adequate characteristics.

STUDY PROGRAMME 8A/I *

FREQUENCY STABILIZATION OF TRANSMITTERS

The C.C.I.R., (1951 - 1959 - 1963)

CONSIDERING

(a) that degrees of accuracy and stability of the frequency of transmitters, in excess of those required by the Radio Regulations, Geneva, 1959, are available, but that the requirement of such accuracy and stability may conflict with economic considerations and design considerations, such as weight and volume;

(b) that advances in technique are continually being made to obtain high accuracy and stability of frequencies while meeting economic and design requirements;

(c) that oscillators with discrete values of output frequency within a given range (frequency synthesizers), provide high stability of output frequency and will therefore find an ever increasing application in radiocommunications; but that such oscillators may produce oscillations suffering from spurious frequency-modulation;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. to continue to study the statistical distribution of the frequency variations observed on transmitters and to analyse their causes;

2. to consider ways of reducing or eliminating such variations, by using new methods or otherwise, and to recommend new frequency tolerances when practicable;

3. to study the unwanted frequency modulation in oscillators, with a view to determining the cause and the means of reducing this modulation;

4. to establish the limits that should be adopted for the spurious frequency-modulation spectrum to insure the required performance for various services and classes of emission.

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* This Study Programme, formerly Study Programme 183(I), does not arise from any Question under study.

STUDY PROGRAMME 9A/I *

FREQUENCY TOLERANCE OF TRANSMITTERS

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

CONSIDERING

(a) that the Radio Regulations, Geneva, 1959, specify the permissible frequency tolerances for transmitters;

(b) that, in many cases, considerable improvement in spectrum utilization can continue to be obtained by further tightening of frequency tolerances;

(c) that, for some services, a reduction in frequency tolerance to the lowest value possible would, at the present state of development, be useful to increase the signal-to-interference ratio or improve the reliability of systems;

(d) that, in certain cases, a further reduction of frequency tolerance would not in practice increase the number of available channels;

(e) that, in particular frequency bands, the frequency tolerance specified by the Radio Regulations, Geneva, 1959, may approach the minimum useful value for certain categories of stations when using existing techniques and methods of operation;

(f) that it will be of considerable assistance to Administrations, in the future planning of services and in the provision of equipment, to know which frequency tolerances can be considered to be ultimately useful when applying existing techniques and methods of operation;

(g) that, in certain cases, reduction of frequency tolerances is limited by economic or environmental considerations;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. to continue the study of frequency tolerances, with a view to the reduction of the bandwidth required for a given emission;

2. to consider whether or not, in certain cases, it is possible to predict ultimate values of tolerances, which it would not be necessary to make more stringent under currently known conditions of operation:

2.1 in the interest of spectrum economy alone;

2.2 to secure improved system performance or lower mutual interference when this needs more stringent tolerance than that for spectrum economy;

2.3 when economic or environmental considerations make the attainment of particular tolerances under § 2.1 either undesirable or unduly difficult;

3. to indicate which, if any, of the tolerances specified in the Radio Regulations, Geneva, 1959, have attained the ultimate values mentioned above.

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* This Study Programme, formerly Study Programme 184(I), does not arise from any Question under study.

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LIST OF DOCUMENTS OF STUDY GROUP I (PERIOD 1963-1966)

Doc.	Origin	Title	Reference
I/1	Federal Republic of Germany	Spurious emissions	S.P. 182, § 2
I/2	United Kingdom	Examination of results obtained by the International Special Committee on Radio Interference	S.P. 227B
I/3	Federal Republic of Germany	Spurious emissions	S.P. 182
I/4	United States of America	Classification and designation of emissions	Proposed mod. to Rep. 175
I/5	United States of America	Bandwidths of emissions	S.P. 181,
I/6	United States of America	Bandwidths of emissions	S.P. 181, § 2.3.2.
I/7	The Netherlands	Power of radio transmitters - Relationships between the peak envelope power, the mean power and the carrier power of a radio transmitter	Proposed mod. to Rec. 326
I/8	United Kingdom	Spurious radiation	S.P. 182
I/9	United Kingdom	Spurious radiation of an emission - Design of HF transmitters and their output coupling networks to reduce spurious radiations	S.P. 182
I/10 and Corr. 1	United Kingdom	Frequency stability of transmitters	S.P. 183 and 184
I/11	C.I.R.M.	Frequency tolerance of transmitters	S.P. 184
I/12	Japan	Measurement of spectra and bandwidths of emissions	Proposed mod. to Rec. 327
I/13	Chairman, S.G. I	Interim Report - Transmitters	
I/14	C.C.I.R. Secretariat	Transmission to S.G. I of Doc. VIII/48	
I/15 (II/17)	C.I.S.P.R.	Report to the C.C.I.R. on the proceedings of the 1964 (C.I.S.P.R.) meeting in Stockholm	Op. 2, Rec. 334 Rep. 182, 183, Q. 227 S.P. 227B
I/16 (XIII/33)	People's Republic of Poland	Proposal for the determination of tolerances for spurious radiation at frequencies above 235 Mc/s	Rec. 329, S.P. 182 Q. 163
I/17	O.I.R.T.	Methods for measuring spurious emissions supplied to the feeder by a single transmitter or a transmitter group	S.P. 182
I/18 and Rev. 1	Working Group I–A	Report to Study Group I	Q. 207, Op. 1. Rep. 175
I/19 (II/29) (V/41)	Study Groups I, II and V	Summary Record of the joint opening session	

Doc.	Origin	Title	Reference
I/20	Study Group I	Summary Record of the first meeting	
I/21	Study Group I	Summary Record of the second meeting	
I/22	Working Group I–C	Spurious radiation (of a radio emission)	Proposed mod. to Rec. 329
I/23	Working Group I–C	Amendments to Study Programme 227B(I)-Bibliography	S.P. 227B
I/24	Working Group I–C	Limitation of radiation from industrial, scientific and medical installations and other kinds of electrical equipment – Proposed International Working Group	Q. 227
I/25	Working Group I–C	Draft Report - Design of HF transmitters and their output coupling networks to reduce spurious radiation	S.P. 182
I/26	Working Group I–C	Report by the Chairman	
I/27	Working Group I–D	Frequency stabilization of transmitters	Proposed mod. to Rep. 180
I/28	Working Group I–D	Report with respect to Doc. I/14	
I/29	Study Group I	Summary Record of the third meeting	
I/30	Working Group I–B	Proposed amendments to Recommendation 326	Rec. 326
I/31	Working Group I–B	Report by the Chairman	
I/32	Study Group I	Summary Record of the fourth meeting	
I/33	C.C.I.R. Secretariat	List of participants	
I/34	C.C.I.R. Secretariat	List of documents issued (I/1 to I/34)	
I/35	United Kingdom	Proposed modification to Study Programme 181(I) – Spectra and bandwidths of emissions	S.P. 181
I/36	United Kingdom	Proposed additions to Report 181 – Frequency tolerance of transmitters	S.P. 184 Rep. 181
I/37	United Kingdom	Bandwidth of emissions	S.P. 181
I/38	United States of America	Proposed modification to Recommendation 327 – Measurement of spectra and bandwidths of emissions	Rec. 327
I/39	United States of America	Proposed modification to Report 181 – Frequency tolerance of transmitters	Rep. 181
I/40	U.S.S.R.	Measurement of the spurious radiation power of short-wave transmitters with a balanced feeder system working in the 1.5 – 230 Mc/s band	S.P. 182
I/41	United States of America	Proposed modification to Study Programme 181(I) – Spectra and bandwidths of emission	S.P. 181
I/42	Japan	Proposed modification to Recommendation 327 – Measurement of spectra and bandwidths of emissions	Rec. 327

Doc.	Origin	Title	Reference
I/43	F.R. of Germany	Bandwidth of emissions	S.P. 181
I/44	F.R. of Germany	Bandwidth of emissions	S.P. 181
I/45	U.S.S.R.	Choice of parameters for harmonic filters at the input of the antenna feeder	S.P. 182
I/46	U.S.S.R.	Determination of the relationship between the highest possible values of the powers of higher harmonics, delivered from a transmitter into the antenna feeder, and the filtering properties of the ouput circuit and of the travelling wave ratios in the feeder	S.P. 182
I/47 (II/60)	U.S.S.R.	Description and technical parameters of a reference oscillator	S.P. 183 Q. 230
I/48	Working Party I/1	Classification and designation of emissions – Letter from the Chairman of Working Party I/1 to the members of the Working Party	Q. 207 Op. 1 Rep. 175
I/49	Japan	The out-of-band radiation of class of emission A3J carrying white noise	S.P. 181
I/50	C.C.I.R. Secretariat	List of documents issued (I/35 – I/50)	
I/51 (VI/189) (XIII/112)	C.C.I.R. Secretariat	Submission of memorandum by the I.F.R.B. – Radio noise in ships	
I/52 and Add. 1	International Working Party I/2	Report by the Chairman	
I/53	Chairman, S.G.I.	Report by the Chairman of Study Group I – Transmitters	
I/54	O.I.R.T.	Spurious radiation due to interaction of transmitters in transmitting centres and receivers	S.P. 182
I/55	O.I.R.T.	Methods for measuring spurious emissions supplied to the feeder by a single transmitter or a transmitter group	S.P. 182
I/56	Netherlands	Proposed modifications to Study Programme 181(I) – Spectra and bandwidth of emissions	S.P. 181
I/57	Netherlands	Memorandum on the definitions of necessary bandwidth and occupied bandwidth	S.P. 181 Rec. 328
I/58 and Corr. 1	Netherlands	Proposed modifications to Recommendation 328 – Spectra and bandwidth of emissions	Rec. 328
I/59	France	Classification of emissions – Test application of the method of classifying emissions submitted by Working Party I-A in its Report to Study Group I (Doc. I/18 (Rev. 1), dated 22 June 1965)	Q. 207
I/60	Study Group I	Summary record of the first meeting	
I/61	Study Group I	Summary record of the second meeting	
I/62	Working Party I/1	Report to Study Group I	Q. 207 Op. 1 Rep. 175

Doc.	Origin	Title	Reference
I/63	Study Group I	Addendum and Corrigendum to Report 176 – Compression of the radiotelephone signal spectrum in the HF bands	
I/64	Study Group I	Draft Report – Interference caused by electrical equipment aboard ships	S.P. 227A
I/65	Study Group I	Draft Recommendation – Methods for measurement of radio-electric interference and determination of tolerable interference levels	S.P. 227B
I/66	Study Group I	Draft Study Programme – Examination of results obtained by the International Special Committee on Radio Interference	
I/67	Study Group I	Draft Study Programme – Protection of radiocommunication equipment from interference by industrial, scientific and medical installations and other kinds of electrical equipment	
I/68	Study Group I	Draft Study Programme – Limitation of unwanted radiation from industrial installations	
I/69	International Working Party I/2	Report by the Chairman	
I/70 (VIII/103)	Study Group I	Draft Report – Approximate methods for the determination of bandwidth	S.P. 180 and 181
I/71	Study Group I	Draft Report A.d(I) – Design of HF transmitters and their output coupling networks to reduce spurious radiations	S.P. 182
I/72	Study Group I	Draft Recommendation A.b(I) – Spurious radiation (of a radio emission)	S.P. 182
I/73	Study Group I	Draft Study Programme – Methods of measuring emitted spectra in actual traffic	
I/74 (VIII/104)	Study Group I	Letter to the Chairman of Study Group VIII – Bandwidth measurements by monitoring stations	
I/75 (VIII/105)	Study Group I	Draft Study Programme – Methods of measuring emitted spectra in actual traffic	
I/76	Working Group I–C	Report to Study Group I	
I/77	Study Group I	Draft Recommendation – Power of radio transmitters	
I/78	Study Group I	Draft Recommendation – Measurements of spectra and bandwidth of emissions	
I/79	Study Group I	Draft Recommendation – Measurements of spectra and bandwidth of emissions	
I/80	Study Group I	Draft Recommendation – Spectra and bandwidth of emissions	

Doc.	Origin	Title	Reference
I/81	Study Group I	Draft Study Programme – Spectra and bandwidths of emissions	
I/82	Study Group I	Summary record of the third meeting	
I/83	Study Group I	Summary record of the fourth meeting	
I/84	Study Group I	Summary record of the fifth meeting	
I/85	Study Group I	Status of texts	
I/86	C.C.I.R. Secretariat	List of documents issued (I/51 to I/86)	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP I

Doc.	Title	Final text
I/1001	Possibilities of reducing interference and of measuring actual traffic spectra	Rep. 178–1
I/1002	Classification and designation of emissions	Op. 1–1
I/1003	Frequency stabilization of transmitters	Rep. 180–1
I/1004	Frequency tolerance of transmitters	Rep. 181–1
I/1005	Classification and designation of emissions	Rec. 432
I/1006	Interference caused by electrical apparatus and installations aboard ships	Rep. 323
I/1007	Compression of the radiotelephone signal spectrum in the HF bands	Rep. 176–1
I/1008	Methods for measurement of radioelectric interference and determination of tolerable interference levels	Rec. 433
I/1009	Examination of results obtained by the International Special Committee on Radio Interference	S.P. 4B/I
I/1010	Protection of radiocommunication equipment from interference by electrical apparatus and installations	S.P. 4C/I
I/1011	Approximate methods for the determination of bandwidth	Rep. 324
I/1012	Design of HF transmitters and their output coupling networks to reduce spurious radiations	Rep. 326
I/1013	Limitation of unwanted radiations from electrical apparatus and installations	S.P. 4A/I
I/1014	Spurious radiation (of a radio emission)	Rec. 329–1
I/1015	Spectra and bandwidth of amplitude-modulated radiotelephone emissions	Rep. 325
I/1016	Methods of measuring spectra of emissions in actual traffic	S.P. 6A/I
I/1017	Power of radio transmitters	Rec. 326–1
I/1018	Spectra and bandwidths of emissions	S.P. 5A/I
I/1019	Measurement of spectra and bandwidths of emissions	Rec. 327–1
I/1020	Spectra and bandwidth of emissions	Rec. 328–1
I/1021	List of documents issued (I/1001 to I/1021)	

RECOMMENDATIONS OF SECTION B (RECEPTION)

RECOMMENDATION 237 *

SENSITIVITY, SELECTIVITY AND STABILITY OF AMPLITUDE-MODULATION AND FREQUENCY-MODULATION SOUND-BROADCAST RECEIVERS

The C.C.I.R., (1956 – 1959)

CONSIDERING

(a) that Recommendation 331–1 gives general recommendations on receiver sensitivity;

(b) that Recommendation 332–1 gives general recommendations on receiver selectivity;

(c) that Recommendation 333 gives general recommendations on receiver stability;

(d) that Publications 69 and 91 of the I.E.C. give definitions concerning the sensitivity, selectivity and stability of amplitude-modulation and frequency-modulation sound-broadcasting receivers and the methods of measuring these properties;

(e) that the I.E.C. is contemplating periodical revision of these definitions and measurement methods;

UNANIMOUSLY RECOMMENDS

1. that, for measuring the sensitivity, selectivity and stability of amplitude-modulation and frequency-modulation sound-broadcasting receivers, the C.C.I.R. should provisionally adopt the definitions and measurement methods contained in I.E.C. Publications 69 and 91 **;
2. that, to the same end, the amendments that the I.E.C. might make to these definitions and measurement methods from time to time be used as a guide by the C.C.I.R.

RECOMMENDATION 239 *

SPURIOUS EMISSIONS FROM BROADCAST AND TELEVISION RECEIVERS

(Question 6/II)

The C.C.I.R., (1956 – 1959)

CONSIDERING

(a) that many receivers produce unwanted emissions, due, for example, to local oscillators or to IF radiation and, in television receivers, to time-base circuits;

(b) that these radiations may emanate from the antenna circuits, the mains supply leads or the receiver chassis and may interfere with many services;

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* This Recommendation, together with Recommendation 330, replaces Recommendations 157 and 158.

** Available from I.E.C. Central Office, Geneva.

*** This Recommendation replaces Recommendation 160.

(c) that considerable progress has been made in national methods of measurement and techniques of reducing unwanted emissions, both of which are particularly useful in the design of receivers (see Docs. 181, 302 and 449, Warsaw, 1956);

(d) that considerable data concerning these radiations have been obtained recently;

(e) that limiting values for such unwanted emissions have been established, based on different methods, by several Administrations;

(f) that international standardization of measuring methods and limiting values is very desirable;

(g) that the I.E.C. has published a work (Publication 106) on the methods of measuring spurious emissions from broadcast and television receivers up to 300 MHz while an extension of the band up to 1000 MHz is being studied;

(h) that the C.I.S.P.R. is studying the level of emissions from such receivers, with a view to establishing tolerable limits;

UNANIMOUSLY RECOMMENDS

1. that the C.C.I.R. be guided by the methods established by the I.E.C. for all types of broadcast and television receivers;
2. that the C.C.I.R. confirm to the C.I.S.P.R. its interest in knowing the level of emissions from receivers and ask to be kept informed of the progress in establishing tolerable limits for such emissions;
3. that all possible means, compatible with economy, should be employed in the construction of receivers to reduce such unwanted emissions.

ANNEX

A considerable amount of data has been produced by different Administrations, as representative of the radiation figures of frequency-modulation and television receivers manufactured during recent years (see Docs. 8, 136, 181, 398 and 449, Warsaw, 1956, and 107, Los Angeles, 1959).

However, since these data were taken by different methods and that a considerable improvement has recently been achieved in reducing receiver radiations, no data have been included here.

Nevertheless, useful information on "conversion factors" from one method to another and on limits that are now accepted for the various methods have been brought to the attention of the C.C.I.R.*. Subjective measurements have confirmed the practical value of the methods mentioned above.**

RECOMMENDATION 330 ***

SENSITIVITY, SELECTIVITY AND STABILITY OF TELEVISION RECEIVERS

The C.C.I.R., (1956 – 1959 – 1963)

CONSIDERING

(a) that Recommendation 331-1 gives general recommendations on receiver sensitivity;

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* Meyer de Stadelhofen. J. *Mesures du rayonnement parasite de récepteurs F.M. exécutées en Suisse par un groupe d'Experts du sous-comité 12-1 (Radiocommunications – S.C. Mesure) de la C.E.I.* – Bulletin Technique des P.T.T., 1956.

** Egidi. C. *Confronto di apparecchiature normalizzate per la misura delle irradiazioni parassite* – Elettronica, 1956.

*** This Recommendation replaces Recommendation 238.

(b) that Recommendation 332–1 gives general recommendations on receiver selectivity;

(c) that Recommendation 333 gives general recommendations on receiver stability;

(d) that Publication 107 of the I.E.C. gives definitions of the sensitivity, selectivity and stability of television receivers and methods of measuring these properties;

(e) that the I.E.C. is contemplating periodical revision of these definitions and measurement methods;

UNANIMOUSLY RECOMMENDS

1. that, for measuring the sensitivity, selectivity and stability of television receivers, the definitions and methods of measurement contained in Publication 107 of the I.E.C.* should be used as a guide by the C.C.I.R.;

2. that, to the same end, the amendments that the I.E.C. might make to these definitions and methods of measurement from time to time should be used as a guide by the C.C.I.R.

RECOMMENDATION 331–1

NOISE AND SENSITIVITY OF RECEIVERS

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

CONSIDERING

(a) that the sensitivity of a receiver is a measure of its ability to receive weak signals, and to produce an output having usable strength and acceptable quality; in many cases, to assess the quality of the output, it might be necessary to take into consideration the receiving equipment as a whole, including the parts giving the information in a printed, aural or visual form;

(b) that the following parameters, which are determined by the particular service for which the receiver is used, are of special importance in relation to sensitivity:

- necessary output level;
- necessary overall signal bandwidth;
- necessary signal-to-noise ratio at the output;

(c) that the following parameters relating to the internal noise of the receiver, which are determined by the receiver design, are also of importance in relation to the sensitivity of the receiver:

- the level of the internal noise, as defined, for example, by the noise factor;
- the width of the effective overall noise band, which is not necessarily identical with the width of the signal band (see Recommendation 332–1);

(d) that, in many cases, to economize in transmitted power, it is desirable that the sensitivity shall be as great as economic and technical considerations permit and is justified by the external noise level;

(e) that the conditions for obtaining high sensitivity, viz. the ability of the receiver to receive weak signals of the desired transmission, should be considered in connection with those for obtaining good protection against interfering signals (see Recommendation 332–1);

(f) that Question 1/II asks for additional data on noise factor and sensitivity for the various types of receiver used for reception of different classes of emission in the different services;

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* Available from the I.E.C. Central Office, Geneva.

(g) that, for the purpose of presenting, comparing, and using data on the sensitivity of receivers, it is desirable to define the following terms:

- maximum usable (noise-limited) sensitivity;
- maximum usable (gain-limited) sensitivity;
- reference sensitivity;
- noise factor;

(h) that often values for noise factor are particularly useful, since they are more uniform than values of maximum usable sensitivity for the various types of receiver used for the reception of different classes of emission in the different services, and other factors remaining unchanged indicate the degree of improvement in maximum usable sensitivity which is theoreticall, possible; y

(i) that the noise factor is useful only for a linear receiver or for the linear part of a receiver, since in a non-linear receiver the noise factor is dependent on the signal input level;

(j) that reference sensitivity is chiefly of value in comparing linear receivers;

(k) that it is desirable to define a "linear" receiver;

(l) that, for radiotelegraphy receivers for automatic reception:

- the use of a non-linear detector, discriminator or telegraph shaping circuit, or the use of narrow-band filters changes the effect of noise from an amplitude variation into a variation of the duration of the telegraph signal elements at the output of the receiver (signal distortion);
- noise may cause mutilation of the signals by splits or extras;
- signal distortion and signal mutilation may cause erroneous characters in the reproduced text;
- the foregoing considerations make it desirable to define receiver sensitivity with reference to signal distortion and mutilation or character errors in the reproduced text;

(m) that for sound broadcast and television receivers, it is desirable to define sensitivity not only for a reasonably good output signal, but also for any usable output signal;

UNANIMOUSLY RECOMMENDS

1. that a *linear* receiver should be defined as one operating in such a manner that the signal-to-noise ratio at the output is proportional to the signal level at the input, and/or to the degree of modulation;

2. that the *noise factor* should be defined as follows: the noise factor is the ratio of noise power measured at the output of the receiver to the noise power which would be present at the output if the thermal noise due to the resistive component of the source impedance were the only source of noise in the system;

3. that the *width of the effective overall noise band* should be defined as the width of a rectangular frequency response curve, having a height equal to the maximum height of the receiver frequency response curve and corresponding to the same total noise power (see Doc. 3, Geneva, 1963);

4. that the *maximum usable sensitivity* should be defined as the larger of the minimum input signal levels (expressed as the e.m.f. of the carrier) *, which must be applied in series with the specified source impedance (dummy antenna), to the input of the receiver to produce at the output;

4.1 – the signal level
or
4.2 – the signal-to-noise ratio (see also § 11)

} necessary for normal operation

when the normal degree of modulation ** is applied to the carrier. If the gain is sufficient

* For frequencies above about 30 MHz the input signal strength is sometimes taken as the available power from the source.

** Class of emission A1 is considered 100% modulated.

to enable both conditions to be satisfied simultaneously, the maximum usable sensitivity is described as "noise-limited". Otherwise, the gain being insufficient, the maximum usable sensitivity is described as "gain-limited"; in this case the gain, being adjusted to a maximum, enables the condition of § 4.1 (necessary output level) to be satisfied without regard to the output noise level (condition of § 4.2);

5. that, for the purpose of presenting and comparing data for particular classes of receivers and classes of emission for the different services (normally noise-limited), and for a particular frequency range, the *reference sensitivity* should be defined as the maximum usable sensitivity for specified values of:

- signal-to-noise ratio;
- receiver bandwidth;
- degree of modulation;
- source impedance (dummy antenna).

Within the linear range the maximum usable sensitivity for any of these conditions should be derived from the reference sensitivity (the noise factor being considered as constant), and vice versa (see Annex II);

6. that in case of nucertainty with regard to terms of the formulae relating noise factor and reference sensitivity (see Annex II), e.g. the width of the effective overall noise band, independently measured values for these two quantities should be given;

7. that values for the maximum usable sensitivity and for the reference sensitivity should be considered in connection with the values for the single signal and multiple signal selectivity (see Recommendation 332–1);

8. that, since the reference sensitivity is of particular value for a receiver working in a linear condition, for the markedly non-linear condition only, the maximum usable sensitivity and the noise factor for the normal operating conditions should be given;

9. that, although radiotelegraph receivers for aural reception can be operated linearly, those for automatic operation, in which non-linearity usually occurs, must be given separate consideration;

9.1 *maximum usable sensitivity* should be defined as the minimum input signal (expressed as the e.m.f. of the carrier), which must be applied in series with the specified source impedance (dummy antenna), to the input of the receiver to obtain at the output the desired signal level and the amount of signal distortion or mutilation permissible in normal operation; the maximum usable sensitivity as defined above should be described as "distortion limited" or "mutilation limited";

9.2 *maximum usable sensitivity, including the reproducing equipment* should be defined as the minimum input signal (expressed as the e.m.f. of the carrier), which must be applied in series with the specified source impedance (dummy antenna), to the input of the receiver to obtain a specified character error rate in the reproduced text;

9.3 defined methods for measuring signal distortion, signal mutilation, element error rates and character error rates should be used (see Doc. 227, Warsaw, 1956; Docs. II/3, II/11 and II/23, Geneva, 1963 and II/62 (U.S.S.R.), 1963-1966);

9.4 for the purpose of comparing and presenting data (see Annex II, § 5), the maximum usable sensitivity should be given for specified values of:

- the amount of signal distortion and signal mutilation at the receiver output with a specified probability of occurrence (see § 9.1 and Annex II, § 5.4); or the character error rate in the reproduced texts (see § 9.2 and Annex II, § 5.5) and the receiver pre-detector and post-detector signal bandwidth;
- the frequency shift for F1 emissions;
- the source impedance (dummy antenna);

9.5 the performance of the receiving equipment in terms of signal distortion, signal mutilation or character error rate, instead of being defined by the maximum usable sensitivity, is often described by the *signal-to-noise* power ratio value in the receiver, just prior to the non-linear part; in this case it is convenient to use a parameter called the "Normalized signal-to-noise ratio" which is defined as the signal-to-noise power ratio per baud per unit bandwidth *; in Annex II, § 6, a formula is given relating the normalized signal-to-noise ratio to the e.m.f. of the carrier at the receiver input (in series with the sources equivalent resistance);

10. that for sound broadcast and television receivers:

10.1 *a maximum sensitivity* should be defined as the minimum input signal applied, in series with the specified source impedance (dummy antenna), to the input of the receiver for which any usable signal with a specified output level can be obtained;

10.2 measurements of sensitivity be made in conformity with Recommendations 237 and 330;

11. that for receivers for mobile services operating at frequencies above 25 MHz, as an alternative to the measurement of signal-to-noise ratio with the wanted modulation removed during the noise measurement, measurements may be made with the wanted modulation present, the output due to this modulation being removed by a filter, when noise and distortion are measured; the ratio in this case is:

$$\frac{\text{signal} + \text{noise} + \text{distortion}}{\text{noise} + \text{distortion}}$$

12. that since measured characteristics vary widely from one receiver to another, measurements should be made as far as possible on several receivers of the same type, and the values given for the type of receiver under consideration should be stated statistically (mean value, standard deviation);

13. that, when a psophometric weighting network is used for sensitivity measurements, this fact should be stated and the response curve given.

Note. – The Annexes listed below give, for reference purposes, the noise and sensitivity values obtained for several types of receiver in current use in certain countries, based on data and information given in Recommendation 234 (Los Angeles, 1959), and Docs. II/3, II/29 and II/31, Geneva, 1962. The data were collected as part of the studies required by Question 1/II

Annex I: Classification of receivers.

Annex II: Formulae relating noise factor and sensitivity of linear receivers. Measurement of, and formulae relating to, sensitivity and normalized signal-to-noise ratio of radiotelegraph receivers for automatic reception.

Annex III: General considerations relating to the noise factor of receivers.

Annex IV: Representative values for the noise factor and reference sensitivity of receivers (excluding television receivers and radiotelegraph receivers for automatic reception).

Annex V: Representative values for the noise factor and sensitivity of radiotelegraph receivers for automatic reception.

Annex VI: Representative values for maximum sensitivity of sound-broadcasting receivers.

Annex VII: Representative values for the sensitivity and noise factor of television receivers

* The normalized signal-to-noise ratio is an energy ratio and it can be expressed in dB (see Report 195).

ANNEX I

CLASSIFICATION OF RECEIVERS

Type of service	Frequency sub-division
1. Telegraphy (aural reception) A1 general purpose A2 mobile service Telegraphy (automatic reception) A1, A2, F1 fixed service	30 – 600 kHz 1 600 – 30 000 kHz 30 – 300 MHz
2. Telephony A3 fixed service, general purpose, mobile service A3B fixed service F3 fixed service, general purpose, mobile service	30 – 600 kHz 1 600 – 30 000 kHz 30 – 300 MHz
3. Sound broadcasting A3	150 – 300 kHz 500 – 1 600 kHz 1 600 – 30 000 kHz
F3	30 – 100 MHz 100 – 300 MHz 300 – 1 000 MHz
4. Television A5 Vision A3, F3 Sound	30 – 100 MHz 100 – 300 MHz 300 – 1 000 MHz

ANNEX II

FORMULAE RELATING NOISE FACTOR AND SENSITIVITY OF LINEAR RECEIVERS. MEASUREMENT OF, AND FORMULAE RELATING TO, THE SENSITIVITY AND NORMALIZED SIGNAL-TO-NOISE RATIO OF RADIOTELEGRAPH RECEIVERS FOR AUTOMATIC RECEPTION

1. A1, A2, A3 emissions (amplitude-modulation)

$$E^2 = 8\,kT\,(BRn/m^2)\,F \times 10^{12} \qquad (1)$$

where:

E : e.m.f. of the carrier (μV) in series with the equivalent series resistance of the source;

F : noise factor (power ratio);

R : equivalent resistance of source (dummy antenna) in ohms;

n : signal-to-noise power ratio at the output;

m : degree of modulation (modulation considered sinusoidal). For A1 emissions, take $m = 1$;

k : Boltzmann's constant $= 1{\cdot}37 \times 10^{-23}$ (J/°K);

T : absolute temperature (°K) (T is commonly taken as 293° K, then $kT \approx 400 \times 10^{-23}$ Joules);

B : width of the effective overall noise band (Hz), taken as the smaller of the two following quantities:
- the post-detection bandwidth;
- half the pre-detection bandwidth (see Note 1).

2. A3B emissions (single-sideband amplitude-modulation)

$$E^2 = 4\ kTBRnF \times 10^{12} \tag{2}$$

where:

E : e.m.f. of the sideband component (μV) in series with the equivalent series resistance of the source;

F, R, n, k and T are as defined in § 1;

B : width of the effective overall noise band (Hz), taken as the smaller of the two following quantities:
- the post-detection bandwidth;
- the full pre-detection bandwidth (see Note 1).

3. F3 emissions (frequency-modulation)

$$E^2 = 8\ kT\,(BRn/q^2)\ F \times 10^{12} \tag{3}$$

where:

$$q^2 = 3\ D^2/B^2$$

E, F, R, n, k and T are defined in § 1;

$2D$: peak-to-peak value of the reference frequency deviation in telephony (modulation considered sinusoidal).

B : width of the effective overall post-detection noise band.

Note 1. – In some cases, it may be sufficient to approximate the bandwidth by taking limiting responses 6 dB below the maximum response; if a more accurate measurement of bandwidth is required, the width of the effective overall noise band may be determined in each case, as explained in § 3 of this Recommendation. It is, however, recommended that a psophometer be used (see § 12 above), since the bandwidth will be known from the psophometer characteristics; this is an advantage since the bandwidth enters the formula to the third power.

Note 2. – Equation (3) is applicable only to a receiver of perfect design working under idealized conditions, that is with:

- *perfect limiting*, in which case no amplitude-modulation remains and the signal-to-noise ratio at the output is proportional to that of the input;
- *receiver noise* mainly produced in the early stages of the receiver.

Equation (3) should not be used to calculate the noise factor from the reference sensitivity and vice versa, unless the conditions above are satisfied.

4. Reference sensitivity (see § 5 of this Recommendation)

The reference sensitivity may be calculated from the noise factor (see Annex III), by means of equations (1) to (3) above or the simplified formula (4) given below:

$$E^2 = CF \tag{4}$$

Typical reference values for B, R, n, m and D are given in Table I below, together with the corresponding values of the multiplying factor C used in formula (4). For ease of computation the values of C given in the Table are in decibels.

While formulae (1) to (4) can also be used to calculate the noise factor from the measured sensitivity, this procedure must be employed with caution, because possible uncertainties in the various parameters (e.g. the effective overall noise band), may lead to less precise values for F than can be obtained by direct measurement (see Annex IV, § 1.2).

5. Measurement of maximum usable sensitivity and normalized signal-to-noise ratio of telegraph receivers for automatic reception (see Doc. 227, Warsaw, 1956; Docs. II/3, II/11, II/21 and II/23, Geneva, 1963)

5.1 The input signal should be modulated by a square wave at a frequency suitable for the receiver, a frequency corresponding to 50 bauds being used where appropriate;

5.2 the recommended values for the frequency shift for F1 transmissions are 400 Hz, 200 Hz and 100 Hz; the receiver bandwidth just prior to the non-linear part of the receiver and that of the post-detector low-pass filter should be chosen in conformity with those given in:
Recommendation 328–1, §§ 2.1, 2.2 and 2.5;
Recommendation 338–1, §§ 1.1 and 1.2;

5.3 the source resistance should be taken as 75 ohms;

5.4 the amount of distortion or mutilation in the receiver should be taken as that one of the following two conditions which requires the greater signal input:
- 20% distortion with a probability of 1 element in error per 1000;
- one split or extra in 1000 elements (see § 9.1);

5.5 the character error rate in the reproduced text should be taken as 1 in 1000 (see § 9.2).

An indication of the critical input level for distortion or mutilation limited sensitivity can be obtained, by observing the shape of the signal at the receiver output on an oscilloscope or on a recording apparatus or by observing the appearance of wrong characters in the reproduced text on a printing apparatus. As this procedure is found to be fairly critical, a useful criterion can thus be obtained in a simple way.

6. Formulae relating "normalized signal-to-noise ratio" and sensitivity (see Report 195)

6.1
$$E^2 = 4\, kTRB_i n_i\, F \times 10^{12}$$

E, F, R, k, T are as defined in Annex II, § 1

B_i = receiver bandwidth, just prior to the non-linear part

n_i = signal-to-noise power ratio, just prior to the non-linear part = $n_c\, S/B_i$;

n_c = being the normalized signal-to-noise ratio

S = keying speed (bauds)

6.2
$$E^2 = 4\, kTR\, n_c\, FS \times 10^{12}$$

If $R = 75\ \Omega$

$$E^2 = C_1\, F\, n_c\, S$$

C_1 = —59·2 dB

6.3
$$E^2 = C_2\, F\, n_c$$

C_2 = —42·2 dB for 50 bauds
= —39·2 for 100 bauds.

TABLE I

Typical reference values for parameters used in calculating and measuring reference sensitivity

Class of emission	Service	Effective overall noise band B (Hz)	Source resistance R Ω	Output-signal-to-noise power ratio n (dB)	Degree of modulation: factor m	Degree of modulation: (kHz)	Peak system deviation for F3 (kHz)	10 log C (dB)
A1	General purpose	1000	75	20	1			—6·2
	Mobile	1000	75	20	1			—6·2
A2	General purpose	1000	75	20	0·3			+4·3(1) —6·2(2)
	Mobile	1000	75	20	0·3			+4·3(1) —6·2(2)
A3	Fixed General purpose Mobile	3000	75	20	0·3			+9·1
	Sound-broadcast (MF) domestic use	5000	dummy anten.(3)	20	0·3			
	Sound broadcast (HF) — domestic use	5000	dummy anten.(3)	20	0·3			+18·3
	Sound broadcast (HF) — professional use	5000	75	20	0·3			+11·1
A3B	Fixed	3000	75	20				—4·4
F3	Fixed General purpose Mobile	3000	75	20	0·3	±4·5(5)	±15	—9·7
	Sound-broadcasting	5000	75	20(4)	0·3	±22·5(5)	±75	—17·0
		5000	75	40	0·3	±22·5(5)	±75	+3
		5000	75	20(4)	0·3	±15(5)	±50	—13·8
				40	0·3	±15(5)	±50	+6·2
		5000	300	20(4)	0·3	±15(5)	±50	—7·8
				40	0·3	±15(5)	±50	+12·2

(1) Without IF oscillator.
(2) With IF oscillator.
(3) The values of the elements of the dummy antenna are shown in Fig. 1.
(4) The value of 20 dB for signal-to-noise ratio was used in recording the measurement values in Table IV, but for future measurements, a signal-to-noise ratio of 40 dB should be used.
(5) This number represents 30% of reference peak deviation (telephony 15 kHz – sound broadcasting 75 and 50 kHz).

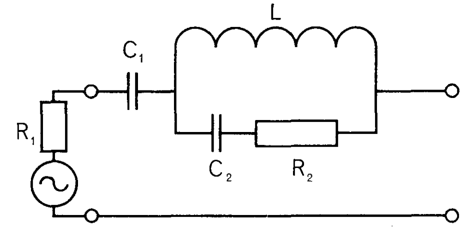

FIGURE 1 – *Dummy antenna*

$C_1 = 125$ pF
$C_2 = 400$ pF
$L = 20$ μH
$R_1 = 80$ Ω
$R_2 = 320$ Ω
$Q_L > 15$ (at 1 MHz)

TABLE IA

Typical values for parameters used for non-linear receivers, measured according to § 11

Class of emission	Service	Effective overall noise band B (Hz)	Source resistance R Ω	Output-signal-to-noise-power ratio n (dB)	Degree of modulation		Peak system deviation for F3 (kHz)
					factor m	(kHz)	
A3	Mobile	3000	75	12	0·3		
F3	Mobile	3000	75	12	0·6 0·6	±9 ±3	±15 ± 5

ANNEX III

General considerations relating to the noise factor of receivers

In a well designed receiver, noise originating in the receiver is mainly due to the random voltages (thermal and shot-noise), generated in the early stages of the receiver, including that portion of the antenna circuit contained within the receiver.

Noise factors below 14 dB for frequencies up to 10 GHz can be obtained with modern receivers (e.g. with parametric amplifiers).

When, however, either the external noise level or the input signal level is high, the receiver noise factor becomes less important. For this reason, some receivers (e.g., many broadcast receivers), are not designed to have the best possible values of reference sensitivity or of noise factor (see § 4 of this Recommendation).

The measurement of noise factor is generally best carried out by means of the noise-generator method (particularly for frequencies above 30 MHz) (see Doc. 117, London, 1953).

When the receiver contains a non-linear element (e.g., a detector, limiter or discriminator), it is desirable that overall measurements of noise factor be made under conditions of linear operation, such as may be obtained by simultaneous injection of a carrier at an appropriate frequency and level (see Docs. 197 and 235, London, 1953).

ANNEX IV

Representative values for the noise factor and reference sensitivity of receivers (excluding television receivers and radiotelegraph receivers for automatic reception)

1. Introduction

1.1 In the following Tables, an attempt has been made to present in a systematic way representative data for noise and sensitivity characteristics of the various classes of receiver. To facilitate the use of these data and at the same time to reduce the amount of data presented, in general only three figures (called for convenience " maximum ", " mean ", and " minimum " values), have been given for each characteristic for a number of similar receivers in each class. The terms *maximum, mean,* and *minimum* refer to *values expressed in decibels* for sensitivity or noise factor according to the column. It is important to note therefore, that for a given case, the *maximum value* in the sensitivity column indicates a poorer *sensitivity* than that of the *minimum* value. For some medium-frequency sound broadcasting receivers, statistical values (mean values and standard deviation) are given.

1.2 It was found that the values for maximum usable sensitivity, reference sensitivity and noise factor, obtained from the different sources, were not always consistent with formulae (1) to (4) in Annex II. As the values for noise factor were considered more reliable in such cases, these were taken as the basic information, and the values for reference sensitivity given in the Tables in this Annex were derived from those for the noise factor by the use of formula (4) in Annex II.

2. Notes to Tables III to V

Column No.

(1) Class of emission.

(2) Service.

(3) Frequency range.

(4) See § 1.1 of this Annex.

(5) *Reference sensitivity.* See § 5 and Annex II, § 4 of this Recommendation; the values for the reference sensitivity given in the Tables assume the reference values for overall noise-band, source resistance, output signal-to-noise ratio and degree of modulation (frequency-shift or deviation in frequency-modulation receivers), given in Table I of Annex II.

(6) *Noise factor* – See § 2 and Annex II and Annex III of this Recommendation.

(7) *Reference bandwidth* – See Annex II, Table I of this Recommendation.

(8) *Remarks.* This column contains information on the number of receivers on which the representative values for noise and sensitivity are based and, when possible, some indication of the spread of the data.

TABLE III

Reference sensitivity and noise factor for radiotelegraphy receivers
(aural reception)(1)

Class of emission	Service	Frequency range (MHz)		Reference sensitivity (dB rel. to 1 μV)	Noise factor (dB)	Reference bandwidth (Hz)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A1	General purpose	1·6–30	Max. Mean Min.	+ 7·8 + 2·8 − 1·2	14 9 5	1000	Several receivers tested
	Mobile	1·6–30	Max. Mean Min.	+11·3 + 5·8 + 0·3	17·5 12 6·5	1000	Few receivers tested

(1) See Annex IV to Recommendation 154, Warsaw, 1956

TABLE IV

Reference sensitivity and noise factor for radiotelephony receivers[1]

Class of emission	Service	Frequency range (MHz)		Reference sensitivity (dB rel. 1 μ V)	Noise factor (dB)	Reference bandwidth (Hz)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A3	Fixed	1·6–30	Max. Mean Min.	+19·1 +16·1 +11·1	10 7 2	3000	Several receivers tested
	General purpose	1·6–30	Max. Mean Min.	+23·1 +17·1 +11·1	14 8 2	3000	Several receivers tested
	General purpose	30–300	Max. Mean Min.	+29·1 +18·6 +11·1	20 9·5 2	3000	Few receivers tested Frequency range = 20–155 MHz
	Mobile	30–300	Max. Mean Min.	+22·6 +18·5 +15·1	13·5 9·4 6	3000	Several receivers tested
A3B	Fixed	1·6–30	Max. Mean Min.	+ 5·6 + 2·6 − 0·4	10 7 4	3000	Several receivers tested
F3	Fixed	30–300	Max. Mean Min.	+ 5·3 + 1·3 − 1·7	15 11 8	3000	Few receivers tested Frequency range = 80–200 MHz
	General purpose	30–300	Max. Mean Min.	+ 1·8 − 2·1 − 5·4	11·5 7·6 4·3	3000	3 receivers tested on the same type Freq. range = 24–184 MHz
	Mobile[2]	30–300	Max. Mean Min.	+ 7·3 + 0·8 − 3·7	17 10·5 6	3000	Many receivers tested Freq. range = 60–200 MHz

(1) See Annex IV of Recommendation 154, Warsaw 1956, and Doc. II/32, Geneva, 1958.
(2) See also Doc. 445, Warsaw, 1956.

TABLE V

Reference sensitivity and noise factor for sound-broadcast receivers(1)

Class of emission	Service	Frequency range (MHz)		Reference sensitivity (dB rel. 1 μ V)	Noise factor (dB)	Reference bandwidth (Hz)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A3	Sound broad-casting	500–1600 kHz	Mean	+35·5		5000	Mass-produced receivers(2) Standard deviation = 3·5dB Source impedance dummy antenna
		1600–30 000 kHz	Mean	+38·7	20·4	5000	Mass-produced receivers(2) Source impedance=dummy antenna (400 ohms)
		1600–30 000 kHz	Max. Mean Min.	+32·1 +25 +17·1	21 13·9 6	5000	Several receivers tested, one RF stage Source impedance=75 ohms
		30–300 MHz	Mean	+19·1	8	5000	

(1) See Annex IV to Recommendation 154, Warsaw, 1956.
(2) See Doc. 398, Warsaw, 1956.

ANNEX V

REPRESENTATIVE VALUES FOR THE NOISE FACTOR AND SENSITIVITY OF RADIOTELEGRAPH RECEIVERS FOR THE FIXED SERVICES (AUTOMATIC RECEPTION)

1. Introduction

In the following Tables an attempt has been made to present, in a systematic way, representative data for noise and sensitivity characteristics of radiotelegraph receivers for A1 and F1 emissions and for the fixed services (automatic reception).

The sensitivity characteristics comprise data for sensitivity, limited by signal distortion or signal mutilation at the receiver output and for sensitivity representative for the performance of the receiving equipment as a whole, including the reproducing equipment.

2. Notes on Tables VI to IX

In *Table VI* information of a general character, pertaining to the Tables VII to IX has been given, including figures for the noise factor (maximum, mean and minimum values) of A1 and F1 receivers for the fixed services.

Tables VII to IX.

Column No.

(6) *Sensitivity criterion.* It has been indicated, whether the sensitivity should be considered as " distortion limited, *D*, " or " mutilation limited, *M*, ".

(7) *Normalized signal-to-noise ratio* (see § 9.5).

(8) *Noise factor.* Only the mean value taken from the noise factor figures contained in Table VI has been used in these Tables.

(9) *Sensitivity.* The data are given in conformity with the recommended measurement characteristics described in Annex II, § 5.

Note. – In view of the small number of receivers tested, the data for normalized signal-to-noise ratio and sensitivity should be considered as provisional.

The relation between normalized signal-to-noise ratio, sensitivity and noise factor is given in Annex II, § 6.

TABLE VI(1)

Noise factor of A1 and F1 receivers for the fixed services

Class of emission	Service	Frequency range (MHz)		Noise factor (dB)
(1)	(2)	(3)	(4)	(5)
A1 F1	Fixed	1·6–30	Max. Mean Min.	10 7 4

(1) See Annex IV of Recommendation 154, Warsaw, 1956 and Docs. II/3, II/21 and II/32, Geneva, 1958.

TABLE VII

Sensitivity of radiotelegraph receivers (automatic reception) (A1)(1)

(Signal distortion and signal mutilation)

Class of emission	Frequency range (MHz)	Frequency shift (Hz)	Keying speed (bauds)	Filter bandwidth (Hz)		Sensitivity criterion M= mutilation D= distortion	Normalized signal-to-noise ratio (dB)	Assumed noise factor (dB)	Sensitivity for 1 failure in 1000 elements (dB rel. 1 μV)	Remarks
				Pre-detection	Post-detection					
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)
A1 (Fixed services)	1·6–30		50	1000	75	M	27·7	7	− 7·5	Three receivers tested
				1000	120	M	26·2	7	− 9	
				1000	250	M	20·2	7	−15	
			100	1000	120	D	24·7	7	− 7·5	
				1000	250	D	22 2	7	−10	

Source impedance = 75 ohms

(1) Calculated from data given in Doc. II/21, Geneva, 1958, according to Annex II, § 6.

TABLE VIII

Sensitivity of radiotelegraph receivers (automatic reception) (F1)(1)

(Signal distortion and signal mutilation, i.e. element error-rate)

Class of emission	Frequency range (MHz)	Frequency shift (Hz)	Keying speed (bauds)	Filter bandwidth (Hz)		Sensitivity criterion M = mutilation D = distortion	Normalized signal-to-noise ratio (dB)	Assumed noise factor (dB)	Sensitivity for 1 failure in 1000 elements (dB rel. 1 μV)	Remarks
				Pre-detection	Post-detection					
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)
F1 (Fixed services)	1·6–30	400	50	1000	75	M	16·7	7	−18·5	Four receivers tested
				1000 or 1500	120	M	20·7	7	−14·5	
				1000	250	M	18·2	7	−17	
			100	1000	120	D	14·2	7	−18	
				1000	250	D	17·7	7	−14·5	
		200	50	1000	75	M	16·7	7	−18·5	
				1500	120	M	19·2	7	−16	
				1000	250	M	21·2	7	−14	
			100	1000 or 1500	120	D	16·7	7	−15·5	
				1000	250	D	22·7	7	− 9·5	
	12·1 (1·6–30)	200 400 800	50	1250	200	D		7	−11 −15·7 −13·9	Ten receivers tested
		200 400 800	171 3/7	1250	200	D		7	— −14·1 −11·4	One receiver tested
		200 400 800	50	300 600 1400	100	D		8·5	−15·7 −13·8 −14·0	Twelve receivers tested
		200 400 800	171 3/7	300 600 1400	100	D		8·5	−10 −12·3 −12·6	One receiver tested

Source impedance = 75 ohms

(1) Calculated from data given in Docs. II/3 and II/21, Geneva, 1958 and Doc. JI/3, Geneva, 1962, according to Annex II, § 6.

TABLE IX

Sensitivity of radiotelegraph receivers (automatic reception) (F1)(1)

(Character error-rate)

Class of emission	Frequency range MHz	Frequency shift (Hz)	Keying speed (bauds)	Filter bandwidth (Hz)			Normalized signal-to-noise ratio (dB)	Noise factor (dB)	Sensitivity for 1 failure in 1000 characters (dB rel. 1 μV)	Remarks
				Pre-detection	Post-detection					
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)
F1 (Fixed services)	1·6–30	400	50	(2)	45		17	7	−18·2	Two receivers tested
		400	50	(2)	90		19	7	−16·2	
		400	50	(2)	180		23	7	−12·2	
		200	50	(2)	100		19·2	7	−16	

Source impedance = 75 Ω

(1) Doc. 2, Warsaw, 1956, and Docs. II/3, II/11 and II/23, Geneva, 1958.
(2) Pre-detector bandwidth unknown.

ANNEX VI

TABLE X

Maximum sensitivity for sound broadcasting receivers(1)

Class of emission	Service	Frequency range (MHz)		Maximum sensitivity (dB rel. 1 μV)	Remarks
F3	Sound broadcasting	86–100	Max.	36	Superheterodyne. Battery receiver with 3 IF stages and ratio detector. Two receivers tested.
			Min.	14	
			Max.	25	Mains receiver. Four receivers tested
			Min.	3	

(1) See Doc. II/21 of Geneva, 1958.

Source impedance = 75 Ω
Deviation = ±22·5 kHz
Output level = 50 mW

ANNEX VII

REPRESENTATIVE VALUES FOR THE SENSITIVITY AND NOISE FACTOR OF TELEVISION RECEIVERS

1. Introduction

1.1 The methods of test of television receivers have not, as yet, been fully standardized in the various countries and the data given in this Annex and the relevant documents must be regarded as tentative until such standardization is more complete (see Recommendation 330).

1.2 The Tables contain representative values for the sensitivity * of the vision and sound channels of typical television receivers, as required by Question 1/II.

The data given in the Tables are deduced from information contained in Docs. 116 and 118 of London, 1953, Docs. 199, 215 and 398 of Warsaw, 1956 and Docs. II/3 and II/21 of Geneva, 1958.

2. Notes to Table XI (405-line system)

Column No.

(1) (2) (3) (5) and (6) The significance of these columns is the same as for the columns with corresponding titles in Annex IV.

(4) The sensitivity of the vision channel has been taken as the larger of the input signal levels required to produce at the output:

(a) a vision signal output level of 20 V (peak-to-peak, black-to-white picture signal);

or

(b) a vision signal-to-noise ratio of 30 dB (peak-to-peak values of vision signal and r.m.s. values for noise).

* The signal levels in Tables XI to XIV are given in dB relative to 1μV, because these data were compiled before the I.E.C. procedures, recommending the specification of signal levels in dBmW, came into general use.

If the gain is insufficient to enable *(a)* and *(b)* to be satisfied simultaneously, the receiver is referred to as gain-limited; otherwise it is noise-limited. If, on the other hand, *(a)* being satisfied, *(b)* is the signal-to-noise ratio for any usable picture, the sensitivity should be described as " maximum sensitivity ".

The sensitivity is stated as the r.m.s. value of the input carrier corresponding to peak white modulation (positive modulation system); a carrier, sinusoidally modulated to a depth of 50%, corresponding to a black-to-white picture signal in a system with 70/30 picture/synchronizing-pulse ratio, is assumed for test purposes.

The following values are also assumed:

Source resistance = 75 Ω

Width of overall effective noise band = 3 MHz.

The reference values for the output signal/noise ratio of the sound channel, the width of the overall effective noise band and the modulation of the test signal, are the same as for sound broadcasting receivers (see Annex II, Note 1, and Table I).

3. Notes to Tables XII and XIII (625-line system)

Column No.

(1) (2) (3) (5) and (6) The significance of these columns is the same as for the columns with corresponding titles in Annex IV.

(4) The sensitivity of the vision channel has been taken as the input signal required to produce at the output:

(a) a vision signal output level of 20 V (peak-to-peak, black-to-white picture signal) (Table XII), or standard image of maximum subjective brightness of white = 20 nits (6 ft. lamberts) and contrast = 10 (Table XIII);

(b) a vision signal-to-noise ratio of approximately 38 dB (peak-to-peak values of vision signal and r.m.s. values for noise), a 38 dB signal-to-noise ratio being considered as a value for a good picture.

If the gain is insufficient to enable *(a)* and *(b)* to be satisfied simultaneously, the receiver is referred to as " gain-limited ", otherwise it is " noise-limited ".

On the other hand, if *(a)* is satisfied and if the signal-to-noise ratio defined in *(b)* refers to " any usable " picture, the sensitivity should be described as " maximum sensitivity " (see Doc. 398, Warsaw, 1956 and Doc. II/3, Geneva, 1958).

The sensitivity is stated as the r.m.s. value of the input carrier, modulated sinusoidally to a depth of approximately 85%. The following reference values are assumed:

Source impedance = 75 Ω

Width of the effective noise band = 4·6 MHz for 625 lines.

The reference values for the output signal-to-noise ratio of the sound channel, the width of the effective overall noise band, the degree of modulation and, for frequency-modulation, the deviation, are the same as for A3 or F3 sound broadcast receivers (see Annex II, Note 1 and Table I).

4. Notes to Table XIV (819-line system)

Column No.

(1) (2) (3) (5) and (6) The significance of these columns is the same as for the columns with corresponding titles in Annex IV.

(4) See § 3 of Annex VII with:

(a) a vision signal output level of 33·3 V (peak-to-peak);

(b) a vision signal-to-noise ratio of 32 dB (peak-to-peak values of signal and r.m.s. values for noise).

The sensitivity is stated as the r.m.s. value of the input carrier, modulated by a rectangular signal to a depth of 100% at 5000 Hz.

TABLES XI TO XIV

Sensitivity and noise factor for television receivers

Frequency range (MHz)	Class of emission		Maximum usable sensitivity noise-limited	Maximum usable sensitivity gain-limited	Maximum sensitivity	Noise factor (dB)	Remarks
			(dB relative to 1 μV)				
(1)	(2)	(3)	(4)			(5)	(6)
TABLE XI(1) *(405-line systems)*							
41–68	A5 Picture	Max.	56	57	34	14	14 receivers of different types tested (12 noise-limited, 2 gain-limited) Maximum sensitivity for 5 receivers
		Mean	66	54	29	7	
		Min.	38	51	26	4	
	A3 Sound	Max.	28	35	13	13	14 receivers of different types tested (9 noise-limited, 5 gain-limited)
		Mean	21	27	8	8	
		Min.	15	20	7	4	
174–216	A5 Picture	Max.	49		40	8	Four receivers tested
		Mean	—		—	7	
		Min.	40		32	6·5	
	A3 Sound	Max.	20		20	8	Four receivers tested
		Mean	—		16	7	
		Min.	18		11	6·5	
TABLE XII(2) *(625-line system, video band 5 MHz and 525-line system, video band 4·2 MHz)*							
41–68	A5 Picture	Max.				11·8	Mass-production receivers Noise factor for 20 receivers tested
		Mean	43		36	7·5	
		Min.				4	
	F3 Sound	Max.					
		Mean	34·5				
		Min.					
174–216	A5 Picture	Max.				11·8	
		Mean	49		44	7·5	
		Min.				5	
	F3 Sound	Max.					
		Mean	40·5				
		Min.					
470–890	A5 Picture	Max.				18	Ten receivers of different types tested
		Mean				12	
		Min.				9	
TABLE XIII(3) *(625-line system, 6 MHz video band)*							
41–68	A5 Picture	Mean	56	50			Few receivers tested. Receivers of different type and design
TABLE XIV *(819-line system)*							
162–216	A5 Picture	Mean	43	57	33	8	

(1) See Doc. II/29, Geneva, 1962.
(2) See Doc. 398, Warsaw, 1956, II/3, Geneva, 1958 and II/31, Geneva, 1962.
(3) See Doc. 215, Warsaw, 1956.

RECOMMENDATION 332-1

SELECTIVITY OF RECEIVERS

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

CONSIDERING

(a) that the selectivity of a receiver is a measure of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals;

(b) that economy in the use of the radio spectrum requires the maximum selectivity compatible with the technical and economic considerations relating to the particular class of receiver;

(c) that the method of single-signal selectivity is used to express the performance of certain characteristics of the receiver. The measurements are made with sufficiently low levels of input to avoid non-linearity (e.g. overloading) affecting the results; automatic gain control, automatic frequency control, etc., being rendered inoperative;

(d) that measurement of selectivity with more than one signal should be the general method for measuring the selectivity. Sometimes the non-linear effects are numerous, then it will be necessary to select the most representative cases to simplify the measurements;

(e) that defined methods of single-signal and multiple-signal selectivity measurements are desirable to permit comparison of receivers;

UNANIMOUSLY RECOMMENDS

1. that the pass-band of the receiver shall be no wider than is essential for the transmission of the necessary modulation of the wanted signal without significant distortion (see Recommendation 328–1, § 1.2);

2. that in establishing the selectivity of a receiver, account should be taken of:

2.1 the unavoidable spread of the spectrum of signals in adjacent channels (see Recommendation 328–1, §2);

2.2 the limitations of the selectivity of the receiver by unavoidable amplitude non-linearity, e.g. cross-modulation;

2.3 the fact that an excessively large attenuation-slope may lead to serious distortion of the phase/frequency characteristic in the pass-band;

2.4 the fact that *selectivity* and *protection ratios* are different characteristics, the first being a property of the receiver only, the second being an agreed minimum value, taking into account characteristics of the emission, propagation and reception;

3. that the filters which determine the selectivity shall be included as near as possible to the receiver input, and the amplifying stages preceding the filters shall be sufficiently linear, to avoid significant loss of selectivity, e.g. by cross-modulation of the wanted signal by strong unwanted signals;

4. that, for the purpose of studying single-signal selectivity, the following definitions are recommended:

4.1 *pass-band:* the pass-band is the band of radio-frequencies or intermediate-frequencies limited by the two frequencies for which the attenuation exceeds that of the most favoured frequency by some agreed value; in general this value is 6 dB, except for high-quality radiotelephony receivers where the value is 2 dB;

4.2 *attenuation-slope:* the attenuation-slope on each side of the pass-band is the ratio:
- of the difference in the attenuations corresponding to two different frequencies beyond the pass-band;
- to the difference between these frequencies;

4.3 *image-rejection ratio:* the image-rejection ratio is the ratio:

- of the input signal level at the image frequency required to produce a specified output power from the receiver,
- to the level of the wanted signal required to produce the same output power.

The image frequency is the wanted signal-frequency plus or minus twice the intermediate frequency, according to whether the frequency-change oscillator is respectively higher or lower in frequency than the wanted signal-frequency.

If the receiver incorporates more than one frequency change, there will be more than one image frequency, and for each of these will be a corresponding image-rejection ratio;

4.4 *intermediate-frequency rejection ratio:* the intermediate-frequency rejection ratio is the ratio:

- of the level of a signal at the intermediate frequency applied to the receiver input and which produces, a specified output power from the receiver,
- to the level of the wanted signal required to produce the same output power;

4.5 other spurious responses can occur when the intermediate-frequency arises as the sum or the difference of the frequency of an interfering signal and a harmonic of the local oscillator frequency, etc.,

spurious-response rejection ratio: the spurious-response rejection ratio is the ratio:

- of the input level at the interfering frequency required to produce a specified output power from the receiver,
- to the level of the wanted signal to product the same output power;

5. that single-signal measurements be made of the pass-band, the attenuation slope, the image response, the intermediate-frequency rejection and other spurious-response rejection ratios as defined above.

For the attenuation-slope, sufficient indication is generally obtained by considering the frequency difference corresponding to attenuations of 20, 40, 60 and if possible, 80 dB, reckoned from the limit frequencies of the pass-band. When the values thus obtained are essentially equal for the two sides of the pass-band, it is sufficient to give mean values.

For some purposes it is of interest to know the bandwidth at fixed levels corresponding to the above-mentioned attenuations. These figures can easily be deduced from the pass-band and the attenuation-slopes at the different levels (see Fig. 1).

The two methods of the presentation of the single-signal selectivity are very similar and there seems no good reason for preference of one over the other. After the introduction, Geneva, 1951, of the method of presentation by the attenuation slope, this method was used for Tables I, II and III of the Annex.

Since, when plotted in decibels to a logarithmic scale of frequency, the sides of the selectivity characteristics are often almost straight beyond a certain frequency difference relative to the mid-band frequency, the attenuation outside the pass-band can also be expressed as the slope of the attenuation/frequency characteristic, in decibels per octave of the frequency difference. The frequency and attenuation at the starting point of such a slope, relative to the mid-band frequency, should be stated;

6. that, for the purpose of studying the selectivity in the non-linear region with *two or more input signals*, the following definitions are recommended:

6.1 *effective selectivity:* the effective selectivity is the ability of the receiver to discriminate between the wanted signal (to which the receiver is tuned), and unwanted signals (having frequencies generally outside the pass-band), the level of which is such as to produce non-linear effects, the wanted and unwanted signals acting simultaneously. The effective selectivity can be investigated by measuring blocking, adjacent-signal selectivity (adjacent-channel selectivity, if there is regular channelling) and radio-frequency intermodulation, as follows:

6.2 *blocking:* blocking is measured by the level of an unwanted signal on a near-by frequency, e.g. in an adjacent channel, which results in a given change (generally a reduction), e.g. 3 dB, in the output power due to a modulated * wanted signal of specified level applied to the receiver input:

6.3 *Adjacent-signal selectivity:* adjacent-signal selectivity is measured by the level of a modulated unwanted signal at a nearby frequency which results in an output power from the receiver (sum of the power of all unwanted components) of a specified amount (e.g. 20 dB) below the power due to the modulation of the wanted signal. This measurement includes the effects of cross-modulation and inadequate intermediate-frequency filtering.

During this measurement the wanted signal may either be unmodulated or modulated, the output power due to its modulation being excluded from the measurement by adequate audio-frequency filtering or the use of a wave analyser for measuring the unwanted components. With receivers for amplitude-modulated classes of emission with reduced or suppressed carrier, the wanted signal shall be modulated.

Note. – For single-sideband and independent-sideband emissions, a modulated signal is deemed to comprise a reduced carrier (if applicable) and one sinusoidal component in only one of its sidebands.

6.4 *inter modulation:* inter modulation is measured as the levels of two unwanted signals which, when applied together, produce at the receiver output power, a given level (e. g. 20 dB **), below that due to the normal input signal, when the frequencies F_n' and F_n'' of these two unwanted signals have:

6.4.1 a sum equal to the intermediate frequency ($F_{if} = F_n' + F_n''$), in which case, tests should be made with frequencies such that the unwanted signals will have frequencies close to, but not equal to, half the intermediate frequency;

6.4.2 a difference equal to the intermediate frequency ($F_{if} = F_n' - F_n''$), in which case, tests should be made with frequencies such that the unwanted signal at the lower frequency should have a frequency near to that of the wanted signal, e. g., in an adjacent channel;

6.4.3 a sum equal to the frequency of the wanted signal ($F_d = F_n' + F_n$), in which case, the unwanted signals should have frequencies close to, but not equal to, half the wanted signal;

6.4.4 a difference equal to the frequency of the wanted signal ($F_d = F_n' - F_n''$), in which case, the unwanted signal having the lower frequency should have a frequency near to that of the wanted signal, e. g., in an adjacent channel;

6.4.5 a sum equal to the image frequency ($F_{im} = F_n + F_n''$), in which case, the unwanted signals should have frequencies close to, but not equal to, half the image frequency;

6.4.6 a difference equal to that between the wanted signal and one unwanted signal, the intermodulation product being of the third order $F_d = 2F_n' - F_n''$, in which case, the nearer unwanted signal should have a frequency near to that of the wanted signal, e.g., in an adjacent channel.

Other orders of intermodulation product‿ ay occur; those selected are generally sufficient to describe the performance in respect ‿ intermodulation.

The frequency of one of the unwanted signals should be adjusted to make the interference a maximum, and that of both should be such that the receiver output power is negligible when only one unwanted signal is applied and modulated.

To determine the severity of intermodulation for a range of values of the strength of the wanted signal, a third signal (the wanted signal), should be applied at the frequency to which the receiver is tuned; suitable input levels may be +20 dB, +40 dB, +60 dB and +80 dB relative to 1 µV. (See Note 2.)

The unwanted signals should be equal in level; in receivers for A3 they should be unmodulated because the interference, resulting from the beat between the intermodulation product and the carrier of the wanted signal, is more severe than that due to any modulation;

* Except for A1 signals when an unmodulated carrier is used.

** Other values may be desirable for certain classes of receivers.

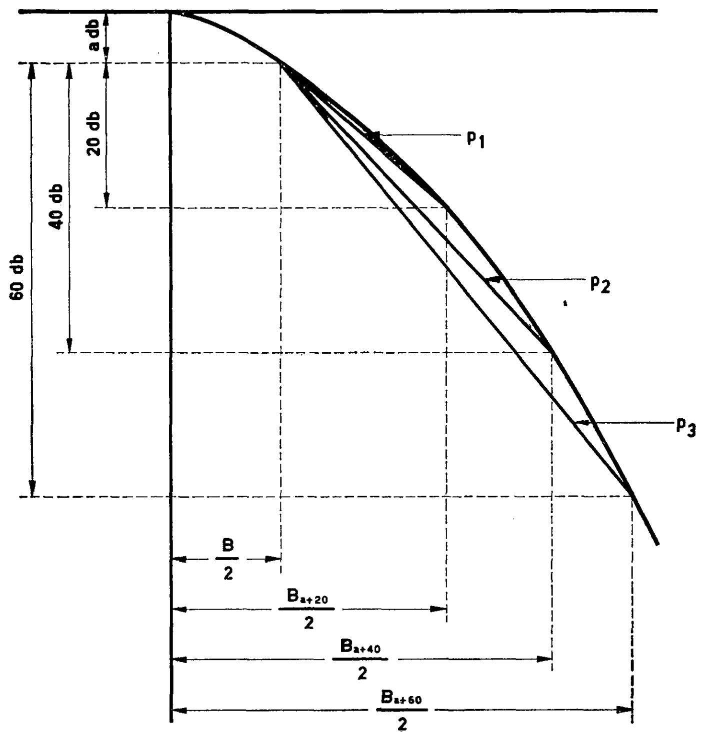

FIGURE 1

Conversion between methods of presentation of single-signal selectivity

The formula: $B_{(a+20n)} = B + 20\ (2n/P_n)$
can be used to convert from the figures given in the tables to bandwidths at specified levels, where:

a = the attenuation at the edge of the passband

$B_{(a+20n)}$ = the bandwidth at a level $(a + 20n)$ dB from the middle of the passband in kHz

B = the bandwidth of the passband in kHz as given in column (5) of Tables I, II and III

P_n = slope of the attenuation in dB/kHz as given in column (6) for:

n = an integer (1, 2, 3 or 4).

in receivers for A3A, A3B and A3J they should also be unmodulated and the frequency of one unwanted signal should be adjusted to make the output power of the receiver have a frequency equal to or, if the signal is filtered out, near to that of the modulation initially applied to the wanted signal.

7. that to express the selectivity in the non-linear region, it is desirable that measurements be made of the effective selectivity in terms of the blocking, adjacent-signal selectivity and radio frequency intermodulation characteristics as defined above.

Note 1. – The application of multiple-signal tests of effective selectivity to receivers for A1, A2, F1 and F3 signals is the subject of further study (Question 3/II).

Note 2. – To enable the measurements to be made with two signal generators, the sensitivity of the receiver can be adjusted by the use of a suitable potential applied to the automatic-gain-control circuit, to correspond to the input signals recommended. In this case, one fh the unwanted signals should be modulated. A correction should be made for the depto of modulation.

Note 3. – Annex I gives representative values for the selectivity of a limited number of receivers (excluding television receivers), and is based on data and information given in the Annex to Recommendation 95 and Docs. 137, 318, 398 and 488, Warsaw, 1956; II/4, II/12, II/16, II/17 and II/25, Geneva, 1958; 89, Los Angeles, 1959, and II/2, II/10, II/23 and II/30, Geneva, 1962.

Annex II gives representative values for the selectivity of television receivers and is based on data given in the Annex to Recommendation 95 and Docs. 137, 398 and 488, Warsaw, 1956; II/25 and II/29, Geneva, 1958 and II/31, Geneva, 1962. Some of the data given in Annexes I and II were collected as part of studies required by Question 3/II.

Annex III gives representative values for the two-signal selectivity of FM broadcast receivers and is based on Doc. II/25, Geneva, 1958.

Annex IV gives representative values for time-delay/frequency characteristics of HF radiotelegraphy receivers and is based on data and information given in Docs. II/14 and II/15, Geneva, 1958.

ANNEX I

SELECTIVITY OF RECEIVERS, EXCLUDING TELEVISION RECEIVERS

1. General

In the following Tables, an attempt has been made to present data for the selectivity characteristics of the various classes of receiver in a systematic way. To facilitate the use of these data and, at the same time, to reduce the amount of data presented, only three figures (called for convenience " maximum ", " mean " and " minimum " values), have been given for each characteristic for a number of similar receivers of each class. This means, that the mean value is taken as a result of figures given either for a larger number of receivers of the same type or for different types of receivers and for different frequencies within the indicated range (Column 3). In most cases, however, the actual frequency range is less than the full indicated range. It should be noted, however, that in many cases, because of the small number of receivers (indicated in the " Remarks " columns of the Tables), these figures have no precise statistical significance.

For certain classes of receiver, only limited data, and in some cases no data, were available. Nevertheless, it is hoped that the incomplete data given in the Tables will be of value to users and that it will be possible to add to these in the future.

2. Notes to Tables I-VI

2.1 *Single-signal selectivity* (See Tables I, II and III)

Column No.

(1) (2) (3) Receivers are tabulated in terms of the class of emission, class of receiver and frequency range respectively, according to the " Classification Scheme for Receivers ", contained in Annex I of Recommendation 331–1.

(4) See § 1 of this Annex (General).

(5) See § 4.1 of this Recommendation.

(6) See §§ 4.2 and 5 of this Recommendation.

(7) See § 5 and Fig. 1 of this Recommendation. The " ultimate slope " is the value generally constant, that the attenuation slope attains at frequencies remote from the pass-band. The frequency and attenuation at the starting point of such a slope, relative to the mid-band frequency, should be stated.

(8) See § 4.3 of this Recommendation.

(9) See § 4.4 of this Recommendation.

(10) This column shows the number of receivers on which the representative values for the single-signal selectivity are based, and, when possible, some indications of the spread of the data.

2.2 *Two-signal selectivity (except intermodulation)* (See Tables IV/1, V/1 and VI/1)

Column No.

(1) (2) (3) See § 2.1 of this Annex.

(4) Frequency difference between the wanted signal, F_a, and the unwanted signal, F_n.

(5) See § 1 of this Annex (General).

(6) See § 6.2 of this Recommendation.

(7) See § 6.3 of this Recommendation.

(8) This column shows the number of receivers on which representative values for the two-signal selectivity are based, and the values for the ratios of the wanted to the unwanted signal at the receiver output (in cross-modulation tests), when these differ from those suggested in § 6.3 of this Recommendation.

2.3 *Multiple-signal selectivity* (See Tables IV/2, V/2 and VI/2)

Column No.

(1) (2) (3) See § 2.1 of this Annex.

(4) Wanted frequency.

(5) See § 1 of this Annex (General).

(6) See § 6.4 of this Recommendation.

(7) This column shows the number of receivers on which the representative values are based.

ANNEX II

Selectivity of television receivers

The methods of test for television receivers have not, as yet, been fully standardized in the various countries. The data given in this Annex and the relevant documents must be regarded as tentative until such standardization is more complete (see Table VII).

Table VII contains representative values for the single-signal selectivity of the vision and sound channels of typical television receivers.

Some results of delay-time measurements of television receivers are given in Doc. 203, Los Angeles, 1959.

ANNEX III

In Table VIII representative figures of the two signal selectivity of FM (F3)-broadcast receivers are shown. The measurements were made in the manner adopted by the I.E.C., in which the ratio of " unwanted-to-wanted signal strength " required to give an interference output 30 dB below the wanted output, with 30% modulation, for various frequency separations, including zero, is measured. (See also Recommendations 237 and 330).

ANNEX IV

Group-delay characteristics of radiotelegraphy receivers

1. General

Table IX shows values of group-delay characteristics of band-pass filters, which are used as IF filters in telegraphy receivers. A short description of the measuring method is given in Report 189.

2. Notes to Table IX

Column No.	
(1) (2) (3) (4)	Classification and single-signal selectivity of receivers tested are shown.
(5)	Group-delay time (ms) at the centre frequency, f_o, of the IF filters.
(6) (7) (8) (9) (10) (11)	Maximum positive and negative deviations of group-delay time within the specified bandwidths, limited by two frequencies at which the attenuations exceed from that at f_o by, 3, 6 and 12 dB respectively.
(12)	Remarks on the design of receivers.

ANNEX I

Table I

Single-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range (MHz)		RF and IF passband (kHz)	Attenuation slope from edge of passband (dB/kHz) 26 dB	46 dB	66 dB	86 dB	Ultimate slope (dB/octave)	Image response ratio (dB)	IF response ratio (dB)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)				(7)	(8)	(9)	(10)
A1	Fixed	1·6–30		1·1	165	200	200	200		113/83		1 receiver tested
		1·6–30		0·4 1·2	108 130	135 165	144 183	130 210		100 100	100 100	
		3–24		0·4	95	120	150					
				1·0	60	65	65			95–131	64–127	$2f_o + f_{if}$: 137 dB $2f_o + f_{if}$: 123 dB $f_o + \frac{1}{2} f_{if}$: 139 dB
				2·1	30	30	30					
	General purpose	1·6–30	Max. Mean Min.	4·7 1·4 0·2	28 16 10	28 15 10	28 15 8			119/53 73/28 41/7	110 90 80	6 receivers tested
		0·03–30	Max. Mean Min.	3·8 3·2 2·4	10·5 8·9 6·7	10·0 7·4 6·5				100 31	110 52	3 receivers tested (different types)
F1	Fixed	3–30		0·6 (1)	77 (1)	77 (1)	77 (1)					Triple frequency-change receiver
	General purpose	3–30		1 (1)	24	24	24					Average type of receiver with 8–10 tubes
				1 (1)	32	32	32					Double frequency-change rec., 20 tubes

(1) At 3 dB down and therefore at 23, 43 and 63 dB instead of 26, 46 and 66 dB (in column 6).

TABLE II–A

Single-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (MHz)		RF and IF passband (kHz)	Attenuation slope from edge of passband (dB/kHz) 26 dB	46 dB	66 dB	86 dB	Ultimate slope (dB/octave)	Image response ratio (dB)	IF response ratio (dB)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)				(7)	(8)	(9)	(10)
A3	Fixed	1·6–30		6	22	23	26·5	28		> 70	>100	
	General purpose	1·6–30	Max.	6·8	12	11	11			119/53	>110	7 receivers tested
			Mean	5·3	8·5	8	8			73/28	> 90	
			Min.	4·0	5	4	4			41/7	> 80	
		0·03–30	Max.	9·4	10·5	10·7				>100	>100	4 receivers (of different types) tested
			Mean	6·1	9·1	9·3						
			Min.	4·3	7·1	6·5				30	81	
		30–300	Max.	52	1·25	1·5	1·5	1·5		100	100	3 groups of 2 receivers (of different types) tested
			Mean	34	1·1	1·2				63	90	
			Min.	16·5	0·84	0·9	0·9	0·9		22	82	
	Mobile	30–300	Max.	65	5	4·4	3·6	3		100	109	3 groups of 4 receivers (of different types) tested
			Mean	37	3·2	2·7	2·3	1·4				
			Min.	22	1·5	1·1	1·5	1·1		60	90	
	Aeron. mobile	225–400		100						> 80	> 80	Double frequency change
A3B	Fixed	1·6–30	Max.	6·4	240	240	240	100		115/85	>110	4 receivers tested for cols. (5) and (6); 3 for (8) and (9)
			Mean	6·15	100	114	118	70		112/84	> 95	
			Min.	6·0	12	12	12	10		110/82	> 80	
		1·6–30	Max.	7·3	45					115	126	23 receivers tested of 4 different types
			Mean	6·9								
			Min.	6·1	13·3					61	60	
		2·5–21		6	50	55	70	37		> 90	> 75	$f_o - f_{if2}$: >78 dB

TABLE II–B

(1)	(2)	(3)	(4)	(5)	(6)				(7)	(8)	(9)	(10)
		30–300 30–300		900 2100	0·35 0·02	0·35 0.02	0·35		200	60 58	80 >100	20 receivers (same type) tested: designed for 24-channel FM system
	Fixed	68–87		30	4·5	4·5	4·5			70	70	
		30–300 (165·7)		46	2·6	3·8	4·4	4·8	140	86	92	Two receivers with double frequency-changing, of the same type
		30–300 (166·75)		46	2·6	3·8	4·4	4·8		79	80	
		170(2)		1500	0·03	0·03				70	140	$2f_o+f_{if}$: > 130 dB
	General purpose	30–300		40	0·8	0·8				90/44	>100	
F3		65–175		28(1)	1·5(1)	1·5(1)	1·5(1)	1·5(1)		> 70	>100	Receiver with continuous tuning. Single frequency change
		30–300	Max. Mean Min.	52 33 21	5·2 2·5 1·4	5·2 2·8 1·7	5·2 3·1 1·1	5·2 3·3 1·1	53(3) 118(3)	96 92 76	100(3)	13 receiver tested (of different types)(3)
		30–300		55	1·2	1·2	1·2	1·1	47	70	80	Portable rec. 25 recs. tested (of 2 types)
	Mobile	68–87·5		30(1)	3(1)	3(1)	3(1)	3(1)		> 70		Fixed frequency rec., double freq. change
				30	1·9	1·9	1·9	1·9				
		31·7–41 67–71 76–88 156–174		30(1)	2·3(1)	2·3(1)	2·3(1)	2·3(1)		> 70		Portable receiver
		405–475		40						> 80	> 80	Triple freq. change
P	Fixed	2100–2300		5000	0·009	0·009	0·009	0·009	22	50	100	1 receiver tested (prototype of 24–channel PPM–system)

(1) At 3 dB down and, therefore, at 23, 43, 63 and 83 dB (2) Measurements made at the single frequency shown. (3) See also Doc. 446, Warsaw, 1956.

TABLE III

Single-signal selectivity of sound broadcast receiver

Class of emission	Service	Frequency range (MHz)		RF and IF passband (kHz)	Attenuation slope from edge of passband (dB kHz)				Ultimate slope (dB/octave)	Image response ratio (dB)	IF response ratio (dB)	Remarks
					26 dB	46 dB	66 dB	86 dB				
(1)	(2)	(3)	(4)	(5)	(6)				(7)	(8)	(9)	(10)
A3 (4)	Sound broad-casting	1·6–30	Max. Mean Min.	13·3 8·05 4·0	4·5 3 6 2·5	3·75 3·1 2·1				44 25 9	120 90 57	10 receivers tested
		0·5–30	Max. Mean Min	15·0 7·3 4·0	8·9 3·3 1·2	6·7 3·4 1·8	6·3 3·1 2·0			78(1) 28(1) 22(1)	100(1) 96(1) 68(1)	169 receivers of about 20 types tested
		0·5–30	Max. Mean Min.	5·8 5·5 5·3	4·5	4·2	3·4					Mean value (taken from a curve); 356 receivers tested
		1(2)		6	3·3	1·3				38	36	$2f_o+f_{if}$: 63 dB $f_o+\frac{1}{2}f_{if}$: 96 dB
		0·5–10	Mean	10·0	4·3	6·1						Low price receiver of 1 type (24 000 tested)
F3	Sound broad-casting	86–100								20 37 21 13	32 42 51 28	FM/AM battery receiver FM/AM receiver FM/AM receiver FM/AM battery receiver
		90(2)		125(3)	0·19(3)	0·17(3)				23	68	FM tuner. Switched with a.f.c. Cheap broadcast receivers
		88–100		165(3)	0·28(3)	0·27(3)						High-quality broad-cast receivers

(1) 3 receivers of different types tested.
(2) Measurements made at the single frequency shown.
(3) At 3 dB down and, therefore, at 23 and 43 dB (in column 6)
(4) Three reference receivers for measurement purposes are described in Report 399.

TABLE IV/1-A

Two-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range MHz	Signal separation F_d-F_n (kHz)		Blocking Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Adjacent-signal selectivity Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Remarks
					+20	+40	+60	+80	+20	+40	+60	+80	
(1)	(2)	(3)	(4)	(5)	(6)				(7)				(8)
A1	Fixed	1·6–30	10		90	105	115	120					1 receiver tested
A1	Fixed	1·6–30	20	Max.	72	80	88	93	69	77	84	89	3 receivers tested
				Mean	69	77	85	91	64	73	81	87	
				Min.	66	73	80	87	63	71	79	85	
A1	General purpose	0·03–30	10	Max.		106	115	123		90	101	113	3 receivers of different types tested at 2 frequencies
				Mean		81	101	115		77	91	104	
				Min.		70	86	104		59	83	100	
F1	Fixed	1·6–30	20	Max.	102	113	>120	>120	96	>120	>120	>120	9 receivers tested
				Mean	94	102	>111	>115	89	>120	>120	>120	
				Min.	85	88	94	102	87	>120	>120	>120	
A1 A2	Fixed	3–24	5	Max.	83	104	111						
				Min.	80	102	108						
			2	Max	72	93	113						
				Min.	72	92	111						

TABLE IV/1-B

Two-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency of wanted signal	$F_d - F_n$	Blocking: Level of unwanted signal (dB rel. 1 µV) that produces 20% distortion once in 1000 elements, or which captures the a.f.c.; the level of the wanted signal being: (dB rel. 1 µV)				Adjacent-signal selectivity: Level of unwanted signal (dB rel. 1 µV) for an output 20 dB below the value; the levels of the wanted signal being: (dB rel. 1 µV)				Inter-modulation: Frequency of wanted signal	Inter-modulation: Levels of two unwanted signals (dB rel. 1 µV) which produce standard output and a signal-to-noise ratio of 20 dB			Remarks
		(MHz)	(kHz)	+20	+40	+60	+80	+20	+40	+60	+80	(MHz)	$F_n' - F_n'' = F_{if}$	$F_n' + F_n'' = F_d$	$F_n' - F_n'' = F_d$	
(1)	(2)	(3)	(4)	(5)				(6)				(7)	(8)			(9)
F1	Fixed	3·1	5	77	92	102	>120									50 bauds. Shift 800 Hz. IF bandwidth 2 kHz
			10	94	100	>120	>120									
			15	100												
A1	Fixed	3·1	5	104												100 bauds. Shift 400 Hz. IF bandwidth 1 kHz
F1	Fixed	3·1	5	>111												
F1	Fixed	3·1	4	109												
F1	Fixed	3·1	3	96												
F1	Fixed	3·1	2	94												
A1	Fixed	3·1	5	91	115											100 bauds. Shift 400 Hz. IF bandwidth 1 kHz
F1	Fixed	3·1	5	111	115											
F1	Fixed	3·1	4	108												
F1	Fixed	3·1	3	100												
F1	Fixed	3·1	2	95												

TABLE IV/2-A

Multiple-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		Intermodulation																								Remarks
					Level of unwanted signals (dB rel. 1 μV) for the levels of the wanted signal given below																								
					$F_n' \pm F_n'' = F_{if}$ cf. § 6.4.1 and 6.4.2						$F_n' \pm F_n'' = F_d$ cf. § 6.4.3. and 6.4.4						$F_n' + F_n'' = F_{im}$ cf. § 6.4.5						$2F_n' - F_n'' = F_d$ cf. § 6.4.6						
					a(1)	0	20	40	60	80	b(1)	0	20	40	60	80	c(1)	0	20	40	60	80	d(1)	0	20	40	60	80	
(1)	(2)	(3)	(4)	(5)	(6)																								(7)
A1	Fixed	1·6–30	10	Max. Mean Min.	(−)			>120 >110 101			(−)			97 90 85															3 receivers tested
				Max. Mean Min.							(+)			115 110 104															
	General purpose	0·03–30	1–10	Max. Mean Min.	(−)		100 79 64				(−)		90 81 72																3 receivers tested
				Max. Mean Min.							(+)		100 87 80																
A1	General purpose	5–22	9				> 95																		65	74	79	86	3 receivers tested (IF 1 MHz)
A1 A2	Fixed	3–24	3–24	Max. Min.	(−)		94 56				(−)		70 60										(−)		60 43				
				Max. Min.							(+)		90 76																
F1	Fixed	1·6–30	10	Max. Mean Min.	(−)			>120 >107 101			(−)			91 86 80															9 receivers tested
				Max. Mean Min.							(+)			104 95 86															

(1) In these columns the values inserted are those for the frequencies given by the following: *(a)* for (+): $(F_n' - \frac{1}{2}F_{if})$; for (−): $(F_n' - F_d)$; *(b)* for (+): $(F_n' - \frac{1}{2}F_d)$; for (−): $(F_n' - F_d)$; *(c)* $(F_n' - \frac{1}{2}F_{im})$; *(d)* $(F_n' - F_d)$.

TABLE IV/2–B

Multiple-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		Intermodulation: Level of unwanted signals (dB rel. 1 μV) for the levels of the wanted signal given below																									Remarks
					$F_n' \pm F_n'' = F_{if}$						$F_n' \pm F_n'' = F_d$						$F_n' + F_n'' = F_{im}$						$2F_n' - F_n'' = F_d$							
					a(¹)	0	20	40	60	80	b(¹)	0	20	40	60	80	c(¹)	0	20	40	60	80	d(¹)	0	20	40	60	80	
(1)	(2)	(3)	(4)	(5)	(6)																									(7)
F1	Fixed	2–30	3·1 Range 1	Distortion 20% once in 1000 elements	(+) 10 kHz		>120	>120	>120	>120	(+) 10 kHz		104	>120	>120	>120	10 kHz		88	102			10 kHz		68	84	92		50 bauds. Shift 800 Hz Filter 2 kHz
					(−) 10 kHz		80	94	105	>120	(−) 10 kHz		78	90	108	>120													
F1	Fixed	2–30	3·1 Range 1	Distortion 20% once in 1000 elements	(+) 5 kHz		>108	>108	>108		(+) 5 kHz		108	108	108		5 kHz		76				5 kHz		77	87	100		100 bauds. Shift 400 Hz Filter 1kHz. A.f.c affected at a slightly higher level of interference
					(−) 5 kHz		>108	>108	>108		(−) 5 kHz		77	89	100														
F1	Fixed	2–30	3·1 Range 1	a.f.c. captured	(+) 5 kHz		>108	>108	>108		(+) 5 kHz		>108	>108	>108		5 kHz		>108	>108	>108		5 kHz		67	77	92		100 bauds. Shift 400 Hz Filter 1 kHz. Distortion increased to 20% at a higher level of interference than that which captured the a.f.c.
				a.f.c. captured	(−) 5 kHz		103	>108	>108		(−) 5 kHz		80	93	101														
			6·0 Range 1	a.f.c. captured							(−) 5 kHz		82	93	101								5 kHz		78	84	97		
			6·0 Range 2	a.f.c. captured	(+) 5 kHz		>108	>108	>108		(+) 5 kHz		>108	>108	>108		5 kHz		>108	>108	>108		5 kHz		79	80	91		
			17·0 Range 3		(−) 5 kHz		>108	>108	>108		(−) 5 kHz		86	105	>108								5 kHz		77	80	90		
			17·0 Range 4		(−) 5 kHz		>108	>108	>108														5 kHz		79	83	91		
F1	General purpose	1·1–30	4		+	>120	>120	>120	>120	>120	+	97	109	117	>120	>120	+	>120	>120	>120	>120	>120	+		100	104	116	>120	One receiver tested
					−	>120					−	82	94	102	114	>120	−	>120					−		90	100	103	110	
F1	Fixed	4–28	4	Max. Mean Min.							+	91 86 82																	Ten receivers tested

(¹) In these columns the values inserted are those for the frequencies given by the following: *(a)* for (+): $(F_n' - \frac{1}{2}F_{if})$; for (−): $(F_n' - F_d)$; *(b)* for (+): $(F_n' - \frac{1}{2}F_d)$; for (−): $(F_n' - F_d)$; *(c)* $(F_n' - \frac{1}{2}F_{im})$; *(d)* $(F_n' - F_d)$.

TABLE V/1–A

Two-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (MHz)	Signal separation F_d-F_n (kHz)		Blocking Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Adjacent-signal selectivity Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Remarks
					+20	+40	+60	+80	+20	+40	+60	+80	
(1)	(2)	(3)	(4)	(5)	(6)				(7)				(8)
A3	Fixed	1·6–30	18	Max.	92	96	101	106	60	74	81	89	4 receivers tested
				Mean	87	93	97	101	57	64	68	76	
				Min.	74	88	94	96	54	56	60	68	
			36	Max.	98	102	105	112	62	80	88	86	
				Mean	97	99	103	107	60	68	72	77	
				Min.	94	96	100	102	56	60	65	72	
	General purpose	1·6–30	10	Max.	86	>120	>120	>120		93	106	115	6 receivers tested
				Mean	75	95	108	117		81	94	101	
				Min.	66	78	94	111		61	79	78	
		0·03–30	10	Max.		119	126	126		109	115	121	4 receivers tested, of different types, at 2 frequencies
				Mean		87	107	120		86	93	97	
				Min.		61	90	108		72	79	85	
		30–300	30			39	67	108		36	51	66	1 receiver tested
			50			62	84	102		48	75	84	1 receiver tested
			300		>100	>100	>100		92	>100	>100		1 receiver tested
	Mobile	0·03–0·6	10		102	112	127				109	114	1 receiver tested
		0·03–30	10							77	89		2 receivers tested
		30–300	50				100						2 receivers tested
			1000								100(1)		

(1) Output level 40 dB below the standard value.

TABLE V/1–B

Two-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (MHz)	Signal separation F_d-F_n (kHz)		Blocking Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Adjacent-signal selectivity Level of unwanted signal (dB rel. 1 µV) for level of wanted signal (dB rel. 1 µV) of:				Remarks
					+20	+40	+60	+80	+20	+40	+60	+80	
(1)	(2)	(3)	(4)	(5)	(6)				(7)				(8)
A3B	Fixed	1·6–30	10	Max.	72	90	110	110	76	92	105	115	3 receivers tested (measured at 3 frequencies)
				Mean	70	89	105	105	72	87	101	105	
				Min.	69	86	104	100	64	84	97	96	
		1·6–30	10	Max.	78	103	118	116	91	94	106	110	23 receivers tested (4 different types, measured at 4 frequencies)
				Mean	70	90	110	111	74	84	101	102	
				Min.	62	77	102	105	60	75	93	95	
		1·6–30	18	Max.	94	105	113	120	73	84	89	94	7 receivers tested
				Mean	88	99	107	113	64	76	82	82	
				Min.	68	79	95	108	53	66	74	72	
		1·6–30	36	Max.	107	114	120	120	86	94	95	96	
				Mean	99	106	112	116	78	87	86	86	
				Min.	82	91	108	111	67	83	74	74	
		2·5 (1)	10	Mean	88		117	115	68		99	102	
		4–20	20	Max.					100	108			
				Mean					90	100			
				Min.					80	95			

(1) Measurements made at the single frequency shown.

TABLE V/1-C

Two-signal selectivity of radiotelephony receivers

Service	Frequency of wanted signal (MHz)	Input level of wanted signal (dB mW)	Unwanted-to-wanted signal ratio (dB) for a wanted-to-unwanted output ratio of 30dB, with frequency separations, of (kHz)									Remarks
			0	−25	+25	−50	+50	−75	+75	−100	+100	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)
F3 Fixed	165·7	−80	−6	− 9	− 7	+55	+53					Two receivers of the same type designed for 50 kHz channel spacing
		−60	−6	− 6	− 5	—	+36					
		−40	−6	+ 1	− 6	—	—					
F3	166·75	−80	−8	+26	+22	—	+57					
		−60	−8	+29	+23	—	—					
		−40	−7	—	—	—	—					

Table V/2-A

Multiple-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		Intermodulation Level of unwanted signals (dB rel. 1 µV) for the levels of the wanted signal given below																								Remarks
					$F_n' \pm F_n'' = F_{if}$ cf. § 6.4.1 and 6.4.2						$F_n' \pm F_n'' = F_d$ cf. § 6.4.3 and 6.4.4						$F_n' + F_n'' = F_{im}$ cf. § 6.4.5						$2F_n' - F_n'' = F_d$ cf. § 6.4.6						
					a(1)	0	20	40	60	80	b(1)	0	20	40	60	80	c(1)	0	20	40	60	80	d(1)	0	20	40	60	80	
(1)	(2)	(3)	(4)	(5)	(6)																								(7)
A3	Fixed	1·6–30	10	Max. Mean Min.	(−)		91 84 79	>104 > 94 81	>104 >101 90	>104 >101 87	(−)		84 80 79	93 86 81	99 95 93	103 101 97													4 receivers tested
				Max. Mean Min.							(+)		86 85 84	86 91 83	>104 >100 99	>104 >103 99													
		5–22	10	Max. Mean Min.			>104 >104 >104		>104 >104 >104																79 78 77				
	General purpose	0·03–30	1 10	Max. Mean Min.	(−)		100 85 63				(−)		90 77 65																Receivers of different types
			20	Max. Mean Min.							(+)		100 93 80																
		30–300	30		(−)		82				(−)		84																1 receiver tested
											(+)		90																
			50		(−)		90				(−)		81																
											(+)		96																

(1) In these columns the values inserted are those for the frequencies given by the following: *(a)* for (+): $(F_n' - \frac{1}{2}F_{if})$; for (−): $(F_n' - F_d)$; *(b)* for (+): $(F_n' - \frac{1}{2}F_d)$; for (−): $(F_n' - F_d)$; *(c)* $(F_n' - \frac{1}{2}F_{im})$; *(d)* $(F_n' - F_d)$.

TABLE V/2-B

Multiple-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		a(1)	0	20	40	60	80	b(1)	0	20	40	60	80	c(1)	0	20	40	60	80	d(1)	0	20	40	60	80	Remarks
					Intermodulation																								
					Level of unwanted signals (dB rel. 1 μV) for the levels of the wanted signal given below																								
					$F_n'\pm F_n''=F_{if}$ cf. §§ 6.4.1 and 6.4.2						$F_n'\pm F_n''=F_d$ cf. §§ 6.4.3 and 6.4.4						$F_n'+F_n''=F_{im}$ cf. § 6.4.5						$2F'-F''=F_d$ cf. § 6.4.6						
(1)	(2)	(3)	(4)	(5)	(6)																								(7)
A3B	Fixed	1·6–30	10	Max. Mean Min.	(−)		> 94 > 92 89				(−)		94 90 88																23 receivers tested
				Max. Mean Min.							(+)		> 96 > 94 > 94																
				Max. Mean Min.	(−)		106 95 75				(−)		109 93 90																
				Max. Mean Min.							(+)		103 93 88																
				Max. Mean Min.	(−)		>104 > 90 68	>104 > 98 79	>104 >102 92	>104 >103 98	(−)		80 73 69	90 83 79	99 92 88	>104 >100 96													7 receivers tested
				Max. Mean Min.							(+)		91 89 77	101 94 90	>104 >102 94	>104 >104 >104													
A3B	Fixed	5–22	9·75	Max. Mean Min.			>104 >104 >104																		64 57 49				
		4–23	10	Max. Mean Min.			>104 >104 >104																		68 65 60				
			10	Max. Mean Min.																					68 68 68				
		4–28									(+)	85 96	94 91	105 104	115 110	>120 >120													2 receivers tested
				Max. Mean Min.							(+)	97 92 87																	7 receivers tested
F3	Fixed	30–300	165·7		(+)25kHz (−)50kHz		> 90 > 90	> 90 > 90	> 90 > 90	> 90 > 90	(+)25kHz (−)50kHz		66 76	70 > 90	 > 90		50kHz		>90	>90	>90	>90	50kHz		60	82	>90		2 receivers with double frequency changing of the same type. Passband 46 kHz
			166·7		(+)25kHz (−)25kHz		> 90 > 90	> 90 > 90	> 90 > 90	> 90 > 90	(+)25kHz (−)50kHz		80 72	84 82	90 88		50kHz		>90	>90	>90	>90	50kHz		52	76	>90		
	Mobile	30–300	160		(−)		> 94				(+) (+)		> 94 > 94																1 receiver tested
			77·4		(−)		96				(−) (−)		87 81																

(1) In these columns the values inserted are those for the frequencies given by the following: *(a)* for (+): $(F_n'-\frac{1}{2}F_{if})$; for (−): $(F_n'-F_d)$; *(b)* for (+): $(F_n'-\frac{1}{2}F_d)$; for (−): $(F_n'-F_d)$; *(c)* $(F_n'-\frac{1}{2}F_{im})$; *(d)* $(F_n'-F_d)$.

TABLE VI/1

Two-signal selectivity of sound-broadcast receivers

Class of emission	Service	Frequency range (MHz)	Signal separation F_d-F_n (kHz)		Blocking Level of unwanted signal (dB rel. 1 μV) for level of wanted signal (dB rel. 1 μV) of:				Adjacent-signal selectivity Level of unwanted signal (dB rel. 1 μV) for level of wanted signal (dB rel. 1 μV) of:				Remarks
					+20	+40	+60	+80	+20	+40	+60	+80	
(1)	(2)	(3)	(4)	(5)	(6)				(7)				(8)
A3	Sound broadcasting	0·5–1·6	10	Max.		72	88	107		61	85	115	3 receivers tested
				Mean		67	86	104		55	79	101	
				Min.		64	86	102		50	73	93	
		0·5–30	10	Max.		79	96	114		76	99	115	3 receivers tested of different types of 3 frequencies; output signal-to-noise ratio 20 dB
				Mean		64	83	102		68	86	104	
				Min.		50	68	85		54	72	94	
		0·5–1·6	20						94		114		Ordinary broadcast receiver(1)
		0·5–1·6	20						109		124		" Narrow " bandwidth } High-quality broadcast receiver
		0·5–1·6	20						102		124		" Wide " bandwidth(1) } High-quality broadcast receiver
F3	Sound broadcasting	30–300	300						46	65	80	90	Several receivers tested
		30–300	300						40	52	60	80	Several receivers tested; output level of undesired signal 40 dB below level of desired signal
		88–100	300					37					Ordinary broadcast receiver(1)
		88–100	300					43					High quality broadcast receiver(1)

(1) Output level of unwanted signal 30 dB less than level of wanted signal.

Table VI/2

Multiple-signal selectivity of sound-broadcast receivers

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		Intermodulation: Level of unwanted signals (dB rel. 1 μV) for the levels of the wanted signal given below — $F_n' \pm F_n'' = F_{if}$ cf. § 6.4.1 and 6.4.2					$F_n' \pm F_n'' = F_d$ cf. § 6.4.3 and 6.4.4					$F_n' + F_n'' = F_{im}$ cf. § 6.4.5					$2F_n' - F_n'' = F_d$ cf. § 6.4.6					Remarks
					a(1)	20	40	60	80	b(1)	20	40	60	80	c(1)	20	40	60	80	d(1)	20	40	60	80	
(1)	(2)	(3)	(4)	(5)	(6)																				(7)
A3	Sound broad-casting	0·5–1·6	1	Max.		>90					>90														7 receivers tested
				Mean	(−)	78				(−)	72														
				Min.		58					53														
				Max.							>90														
				Mean						(+)	76														
				Min.							61														
		0·5–30	1	Max.		90					78														3 receivers tested
				Mean	(−)	70				(−)	70														
				Min.		51					63														
				Max.							90														
				Mean						(+)	82														
				Min.							70														

(1) In these columns the values inserted are those for the frequencies given by the following: *(a)* for (+): $(F_n' - \frac{1}{2}F_{if})$; for (−): $(F_n' - F_d)$; *(b)* for (+): $(F_n' - \frac{1}{2}F_d)$; for (−): $(F_n' - F_d)$; *(c)* $(F_n' - \frac{1}{2}F_{im})$; *(d)* $(F_n' - F_d)$.

ANNEX II

TABLE VII

Single-signal selectivity of television receivers

Class of emission	Frequency range (MHz)		Attenuation (dB, relative to maximum response, at the frequency shown below in (MHz) relative to vision carrier frequency[1])																Image attenuation	Remarks
			±7	±6·5	±6	±5·5	±5	±4·5	±4	±3·5	±3	±2·5	±2	±1	0	∓0·5	∓1	∓1·5		
(1)	(3)	(5)	(6)																(7)	(10)
(a) 405-line system [1]							Adjacent vision carrier			Sound carrier					Vision carrier		Adjacent sound carrier			
A5 (vision)	30–100	Max.					>60	>60	>60	>54	20	5	1	0	9	27	46			4 receivers tested
		Mean					>60	>60	>60	>40	15	3	0	0	6	23	41			
		Min.					40	18	32	36	10	1	0	0	4	20	37			
	30–300	Max.					>50	>50	>50	>60	46	24	6	2	6	18	40			5 receivers tested
		Mean					>40	>40	>37	>50	24	9	2	1	4	13	30			
		Min.					26	26	25	45	6	1	0	0	0	6	17			
		Max.					42	36	35	>50	29	13	4	4	2	15	23			3 receivers tested
		Mean					37	29	28	>50	20	8	1	2	2	10	21			
		Min.					35	25	25	>50	8	1	0	0	0	6	17			
	56·75						41	29	26	58		2	0	0	3	14	20	48		
	41–68	Max.					73	56	52	72	36	16·5	3	1	7	16	29	56		7 receivers tested
		Mean					56	43	41	54	24	7	2	0·5	2·2	8·5	20	42		
		Min.					46	35	25	40	13	1	0	0	0	3·5	12	23		
	174–216	Max.					43	40	42	65	38	18	3	1	5	14	24	46		3 receivers tested
		Mean					40	37	37	54	21	7	1·5	0·5	3	9	17	43		
		Min.					37	33	30	48	12	1	0	0	1	2	6	40		
A3 (sound)	41–68	Max.					70	50	20		12	36	56							4 receivers tested
		Mean					48	32	11	0	10	25	37							
		Min.					27	17	3		5	12	18	37	42	49	60	>80		
	174–216						31	19	2	0	7	14	20	36	40	44	51	66		1 receiver tested
	53·25						43	25	14	0		28	33·5	42	42	48	50	>52		
(b) 525-line system																				
A5/F3	60	Max.																	87	10 receivers of different types tested
		Mean																	59	
		Min.																	42	
	195	Max.																	74	
		Mean																	59	
		Min.																	47	
	470 890	Max.																	57	
		Mean																	40	
		Min.																	28	
(c) 625-line system B - read upper signs; [1]			Adjacent vision carrier			Sound carrier									Vision carrier			Adjacent sound carrier		
A5 (vision)	100–300	Max.	58	38	36	40	12		5		3		1·4	2·5	6	21		45		4 receivers of different types tested
		Mean	43	31	25	23	7·7		1·2		0·7		0·7	0·9		14		40		
		Min.	33	27	12	15	5		0		0		0	0		10		32		
	30–300	Mean	40	23	26	28	16		0·5		0		0	1·5	7·5	16		28		20 receivers tested, each on 5 channels (figs. taken from a curve)
		Mean	+37			+24	+14		−1	−3		−4	−4	−4	0	+7	+17	+22		

[1] The upper sign must be used for the 625-line system and the lower sign for 405-line system.

Rec. 332-1

ANNEX III

Table VIII–A

Two-signal FM (F3) broadcast receiver selectivity

Service	Frequency of wanted signal (MHz)	Imput level of wanted signal (dB (mW))	Unwanted-to-wanted signal input ratio (dB) for a wanted-to-unwanted output ratio of 30 dB with frequency separations (kHz) of									Remarks All new receivers and not realigned before test
			0	±100		±200		±300		±400		
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)
				−100	+100	−200	+200	−300	+300	−400	+400	
F3	94	−80		− 10	− 9·5	+ 1	− 9·5	+ 15·5	− 5·5	+ 26	+ 5	1 RF 2 IF ratio detector
		−60		− 11·5	− 5·5	− 9·5	+ 4	− 4·5	+ 16·5	+ 4·5	+ 27	
		−40		− 10	− 11	− 9·5	− 8·5	− 6	+ 2·5	− 1	+ 20	
	94	−80		− 5	− 10	− 1·5	− 9·5	+ 4·5	− 7·5	+ 12	− 4	1 RF 2 IF ratio detector
		−60		− 6	− 13	− 0·5	− 13	+ 6	− 14	+ 13	− 10	
		−40		+ 0·5	− 1	+ 4	− 0·5	+ 8	+ 2	+ 15	+ 6	
	92	−80		+ 2·5	+ 1	+ 3·5	+ 12	+ 14	+ 24	+ 32·5	+ 36	1 RF 2 IF ratio detector
		−60		− 10·5	− 8	− 7	+ 0·5	+ 2·5	+ 13	+ 14	+ 27·5	
		−40		− 12	− 10	− 7·5	− 4	− 0·5	+ 4·5	+ 8	+ 7·5	
	94	−80		− 10·5	− 6·5	+ 1	+ 4	+ 35	+ 36	+ 44	+ 48	3 IF ratio detector. Battery operated
		−60		− 10·5	− 6·5	0	+ 3	+ 25	+ 21·5	+ 33	+ 33	
		−40		− 11·5	− 11	+ 4·5	− 6		+ 11			
	94	−80		0	− 8	− 3	+ 6	− 3·5	+ 20	+ 11	+ 32	1 RF 1 IF 1 limiter Foster Seeley discriminator
		−60		− 13·5	− 1·5	− 14·5	+ 6	− 10·5	+ 16	+ 5·5	+ 24·5	
		−40		− 13·5	− 11	− 13	+ 0·5	− 12·5	+ 14	+ 2·5		
	92	−80		− 3	− 4	− 2·5	+ 3	+ 5·5	+ 13		+ 24	1 RF 2 IF ratio detector
		−60		− 3	− 3·5	− 1·5	+ 4	+ 3·5	+ 15	+ 13	+ 22·5	
		−40		− 10	− 10	+ 0·5	− 8	− 17·5	− 5·5	− 15	+ 1	
	94	−80		− 7	− 6·5	+ 7·5	− 5	+ 25	+ 9	+ 40	+ 23	1 RF 3 IF ratio detector
		−60		− 6·5	− 5·5	+ 10	− 10	+ 27·5	− 2		+ 15·5	
		−40		− 17·5	− 20·5	− 4	− 21·5	+ 12·5	− 15		+ 2·5	
	92	−80		− 7·5	− 5·5	− 7	+ 0·5	+ 1	+ 8·5	+ 16	+ 18	1 RF 2 IF ratio detector
		−60		+ 1·5	− 7·5	− 3·5	− 2	+ 5	+ 5·5	+ 19·5	+ 15	
		−40		− 7·5	− 11	+ 2	− 6·5		− 11		− 3·5	
	94	−80	− 13	− 9·5	− 6	0	+ 10·5	+ 24·5	+ 32	+ 45·5	+ 48	3 IF ratio detector. Battery operated
		−60	− 12	− 3·5	− 9·5	+ 20	+ 1·5	+ 33	+ 18			
		−40	− 16	− 8	− 13·5	+ 15	− 10		+ 9			

Table VIII-B

Two-signal FM (F3) broadcast receiver selectivity

Service	Frequency of wanted signal (MHz)	Imput level of wanted signal (dB (mW))	Unwanted-to-wanted signal input ratio (dB) for a wanted-to-unwanted output ratio of 30 dB with frequency separations (kHz) of									Remarks All new receivers and not realigned before test
			0	±100		±200		±300		±400		
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)
F3	94	−80	−15	−15	−17	+ 2·5	+ 4	+10·5	+ 5	+17·5	+ 14	1 RF 2 IF ratio detector
		−60	−16	− 5	0	+ 1	+ 9	+ 5	+16	+ 8	+ 22	
		−40	−14	− 1·5	− 1·5	+ 2·5	+ 6·5	+ 4·5	+11	+ 8	+ 15	
	94	−80	− 8	+ 1	− 4	+22·5	+ 2	+37·5	+12	+47·5	+ 37	No RF 2 IF ratio detector
		−60	−14	−11·5	− 7	+ 1	+17·5	+16	+28·5	+26	+ 34	Battery operated
		−40	−10·5	− 6·5	+ 0·5	+ 6·5						
	94·5	−80	−13	− 6	− 6·5	− 1·5	− 4	+ 3·5	+3·5	+13	+ 11	
		−60	−11	− 8	+ 0·5	− 8	+ 4·5	− 1·5	+ 9	+ 7	+ 18	1 RF 2 IF ratio detector
		−40	− 8	− 6	+ 2·5	− 4	+ 6·5	− 3·5	+10	− 0·5	+ 17	
	91·3	−80	−11	− 8	0	− 3	+12	+ 7·5	+22	+20·5	+ 30	1 RF 1 IF
		−60	−11	− 3·5	+ 2	− 8	+16	+ 0·5	+25	+11	+ 33·5	Foster Seeley' discriminator
		−40	−10	− 6	+ 2·5	− 6·5	+12	+ 4·5				
	95	−80	− 9	− 5	− 1	− 1·5	+ 8	+11·5	+18	+25	+ 32·5	
		−60	−11	−12	−25	−10·5	+11·5	+ 3	+25	+22	+ 37	1 RF 2 IF ratio detector
		−40	− 9	− 8·5	− 8	−10·5	− 2	− 4	+ 6·5	+13		
F3	95	−80	−13	−11·5	−10	− 3·5	− 2	+11	+ 9·5	+24	+ 22	
		−60	−11	− 6	5	+ 1·5	+ 2·5	+13	+11	+16·5	+ 17·5	1 RF 2 IF ratio detector
		−40	−12	− 5	− 2	+ 3·5	+ 8	+ 6	+11·5	+ 6		
	94	−80	− 7	− 5		0		+12		−21		
		−60	−11	− 6		+ 2		+13		+24		1 RF 2 IF ratio detector
		−40	−11	− 5		+ 3		+15		>+20		

ANNEX IV

TABLE IX

Group-delay characteristics of radiotelegraphy receivers

Classification (1)	Passband (Hz)	Attenuation slope (dB/100 Hz)		Group-delay time at centre frequency f_o (20 kHz) (ms)	Maximum deviation of group-delay time within the specified bandwidths by attenuations of 3,6 and 12 dB. The value of f_o is taken as a reference (ms)						Remarks
					3 dB		6 dB		12 dB		
		26 dB	46 dB		+	—	+	—	+	—	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1–A	570	7·9	10·3	1·9	0·2	0	0·3	0	0·4	0	Designed for shift width of 400 Hz
2–A	570	8·7	10·5	1·9	0·1	0	0·1	0·1	0·1	0·3	
3–A	656	8·4	11·4	1·8	0·2	0·2	0·2	0·2	0·3	0·2	
4–B	700	18·8	23·0	2·0	2·1	0·1	2·3	0·1			
5–B	700	18·8	23·0	2·3	2·0	0·1	2·0	0·1			
6–A	1070	4·0	4·9	1·2	0	0·3	0	0·5	0	0·5	Designed for shift width of 800 Hz
7–A	1060	4·2	5·4	1·2	0·1	0	0	0·1	0	0·2	
8–A	1092	3·5	5·1	1·2	0·1	0·2	0·1	0·2	0·1	0·2	
9–B	1560	12·2	8·4	0·9	1·3	0·1	1·7	0·1			
10–B	1500	12·2	8·4	1·0	1·2	0·1	1·2	0·1			

(1) In the receivers classified A, the filters used were designed to have flat group-delay/frequency characteritsics, whereas for B, they were designed by conventional methods.

RECOMMENDATION 333 *

TUNING STABILITY OF RECEIVERS

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

CONSIDERING

(a) that the tuning instability of receivers, except at present, for receivers for bands 8 and above, manifests itself as a lowering of the quality of the output signal of the receiver and that it is necessary to limit that instability without resorting to frequent retuning;

(b) that, in receivers for bands 8 and above, the passband of the receiver is greater than the value strictly necessary to admit the modulation of the desired signal without appreciable distortion;

UNANIMOUSLY RECOMMENDS

1. that, where economic considerations prevent the use of more effective devices for stabilizing the tuning of the receiver, all possible steps should be taken to ensure stability of the components in the receiver;

2. that, where a higher degree of stability is required, use should be made of components which determine the frequency with a very high degree of stability, or resort should be made to frequency synthesis;

3. that, where a still higher degree of stability is required, automatic frequency control should be used;

4. that, where very accurate carrier synchronization is required, as for instance in reduced-carrier systems, it is desirable to use an accurate means of automatic control, capable of regulating the frequency of a local oscillator in the receiver in such a way that the carrier at the intermediate frequency is rendered equal, to within a few hertz, to the frequency of another local oscillator used for demodulating the signal. Automatic frequency control is necessary to correct for variations in the carrier frequency due both to propagation effects and to variations in the frequency of the transmitter;

5. that, especially for receivers for reduced carrier transmissions, in which sudden frequency variations of the oscillator may lead to faulty operation of the automatic frequency control, it is desirable that such sudden variations should be avoided;

6. that instability in the electrical or mechanical filters in the receiver, due to variations in humidity and temperature, should be reduced to the minimum;

7. that due care should be taken in the mechanical manufacture of oscillators and filters for the receiver, to reduce to a minimum, frequency variations due to mechanical shock and vibration and, for variable frequency oscillators, attention should be given to the resetting accuracy of the variable capacitors and inductors, and the range-changing switches;

8. that, because of frequency instability arising from the effect of the range-changing switches on oscillator circuits, it is desirable in receivers with several frequency ranges, to avoid the use of such switches, by using single-range oscillators followed by a frequency multiplier.

Note. – The Annex contains typical values of stability for various receivers in certain countries; the values are based on data given in Recommendations 96 and 156, supplemented by information contained in Docs. 3 (F. R. of Germany), 119 (Czechoslovak S. R.), 158 (United Kingdom), 159 (United Kingdom), 160 (United Kingdom), 394 (France) and 398 (Italy), Warsaw, 1956;

* This Recommendation replaces Recommendation 236.

in Docs. II/2 (F. R. of Germany), II/6 (Italy), II/24 (United Kingdom) and II/31 (Czechoslovak S. R.), Geneva, 1958; in Doc. 122 (U.S.S.R.), Los Angeles, 1959 and in Doc. II/9 (United Kingdom), Geneva, 1962. These assembled data constitute a partial reply to Question 4/II.

ANNEX

1. General

In the following Tables an attempt has been made to present, in a systematic way, representative data for the frequency instability (generally of the frequency-change oscillators), for various classes of receiver. To facilitate the use of these data and at the same time to reduce the amount of data presented, only three figures have been given for each characteristic for a number of similar receivers in each class:

- a *minimum* value corresponding to the lowest value obtained during the measurements;
- a *mean* value, corresponding to the arithmetical mean of the values obtained during the measurements;
- a *maximum* value, corresponding to the highest value obtained during the measurements (it might be possible to lower this maximum value should subsequent results reveal a systematic improvement).

It should be noted, however, that in some instances, because of the small number of receivers tested (as indicated in the Remarks column), the figures for the mean value have no precise statistical significance.

Only limited data are available for certain classes of receiver, particularly television receivers and other receivers for frequencies above about 30 MHz approximately.

The following general conclusions may be drawn from the data so far obtained:

1.1 there is a very wide variation in the figures obtained, even for the same type of receiver;

1.2 most receivers reach their working temperature within one hour after switching on, although the use of a thermostatically controlled compartment may prolong the period needed for warming-up.

Tables I to V show representative data for various classes of traffic receiver and other receivers in current use.

Tables VI and VII contain instability values for specially high-grade receivers:

Table VI. – Receivers with compensating capacitors.

Table VII. – Receivers using combined systems (automatic correction or crystal controlled first oscillator);

1.3 little information is available on the instability due to a 20% mains voltage variation or to wide ranges of temperature variation.

2. Notes to the Tables

Column No.

(1) The suffix (L) signifies that the information was extracted from the documents of London (1953); (W) that it was extracted from the documents of Warsaw (1956). Where the information is a combination of that from both sources, the suffix (L W) is used.

(2) (3) The class of emission and type of service are quoted in accordance with Annex I of Recommendation 331–1.

(4) The frequency range quoted is that covering the data given in the appropriate documents, but does not in all cases correspond to the preferred ranges quoted in Annex I of Recommendation 331–1.

(5) This column indicates the type of frequency-change oscillator(s) used in the receiver, e. g. LC-controlled, quartz crystal controlled, frequency synthesizer, double frequency changer, etc. In many cases, sufficient information regarding this point was not available.

(6) See § 1 (General) of this Annex.

(7) Relative frequency-drift during the warming-up period is indicated, without regard to sign, at 1, 10, 30, 60 and 120 minutes after switching on, the value at 60 minutes being used as the reference datum. These figures are given as being of the greatest importance when considering permissible channel spacings. A knowledge of the sign of the drift would be of interest to the designers of receivers, since a change of sign during the warming-up period would indicate some measure of self-compensation in the receiver, different parts of the receiver having different thermal time-constants. The inclusion of this information would, however, make the Table too complicated and is considered unnecessary for the purposes of the C.C.I.R.

(8) The relative frequency variation is the largest of the variations obtained when the power supply voltage varies:

$\pm$ 10% for AC mains supply
$\pm$ 20% for battery supply.

(9) The relative frequency variation is:

- either that due to a variation of 1° C near the normal ambient temperature, especially where thermostatic control is used,
- or that due to variations of temperature over the range shown in the Tables.

(10) The relative frequency variation indicated resulting from light mechanical shock, e. g. due to striking the front of the receiver lightly with the hand. In certain cases, e. g., mobile service receivers, more comprehensive vibration and shock tests are desirable.

(11) This column contains information on the number of receivers used for the determination of the representative values for the frequency drift and variation including, when possible, some indication on the spread of the data; information on the vibration and shock tests referred to under Column (10) above, is also to be included in this Column (11).

TABLE I

Radiotelegraphy receivers

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency changer used		Relative frequency drift (× 10^{-6}) at the following times (in minutes) after switching on					Relative frequency variation (× 10^{-6}) due to supply voltage variation of:		Relative frequency variation (× 10^{-6}) due to temperature variation of:		Relative frequency variation (× 10^{-6}) due to mechanical shock	Remarks
						1	10	30	60	120	10%	20%	1°C	For range shown		
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)		(9)		(10)	(11)
1(L)	A1 A2	Fixed	1·6–30	No	Max. Mean Min.		33 17 3	20 9 0	0 0 0	8 4 1	10		17 7 0			Col. (7): 6 receivers tested Col. (8): 1 receiver tested Col. (9): 7 receivers tested
2(W)	A1 A2 F1	Fixed and mobile	1·5–28	No	Mean	125 109 190	105 42 42	50 26 26	0 0 0	35 4 5	10 1·3 0·8		11 6·4 1·3			f_{osc} = 2 MHz f_{osc} = 16 MHz f_{osc} = 27 MHz Variation over whole range. Only a few receivers tested
3(W)	A1 A2 F1	Fixed	3–30	Yes(1)	Mean	323 122 17	237 66 6	186 19 2	0 0 0	42 13 1	2·9 1·3 3·2					f_{osc} = 7 MHz f_{osc} = 16 MHz f_{osc} = 24 MHz
4(W)	A1,A2 A3 F1	Fixed	2–30	Yes	Max. Mean Min.			110 50 20	0 0 0				2 1 0·4			Several receivers tested
5(L)	A2	Mobile	100–1000	No	Max. Mean Min.						4 3·3 2·6		1·7 1·1 0·4			1 receiver tested

(1) Frequency synthesis employed

TABLE II

Radiotelephony receivers

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency changer used		Relative frequency drift (× 10^{-6}) at the following times (in minutes) after switching on: 1	10	30	60	120	Relative frequency variation (× 10^{-6}) due to supply voltage variation of: 10%	20%	Relative frequency variation (× 10^{-6}) due to temperature variation of: 1°C	For range shown	Relative frequency variation (× 10^{-6}) due to mechanical shock	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)		(9)		(10)	(11)
1(L)	A3	Fixed	1·6–30	No	Max. Mean Min.		33 17 3	20 9 0	0 0 0	8 4 1	<10		17 7 0			Col. (7): 6 receivers tested Col. (8): 1 receiver tested Col. (9): 7 receivers tested
2(LW)	A3B	Fixed	1·6–30	No	Max. Mean Min.		468 184 10·2	176 84 2·1	0 0 0	95 43 12·9	36 1·5		5·5		10 0	Col. (7): 23 receivers tested Cols. (8), (9) and (10): Only a few receivers tested
3(W)	A3B	Fixed	18·4	No	Mean		34	16	0		127				12	Adjustable temperature compensating capacitor used
4(W)	A3 A3B	Fixed	4–28	Yes	Max. Mean Min.						1 0·5 0·2		7 5 3			Several receivers tested
5(W)	F3	Fixed	41–68	No	Max. Mean Min.	640	185	16	0		10(1)		13 10 5·5			24 channel radio-relay link receivers. Only a few receivers tested
6(W)	F3	Fixed	185	No	Mean		5	21	0	21	320				1	Multi-channel receiver. a.f.c. on Osc. 1 with thermostatic control of discrim. Crystal-osc. 2 IF bandwidth 200 kHz
7(W)	F3	Fixed	163·5	Yes	Mean		19	11	0		3·6				3·5	IF bandwidth 35 kHz
8(W)	A3 F3	Mobile	70–200	Yes	Max. Mean Min.	8·5	5·5	2	0	0·9	150 17 1·8	4	0·8 0·5	50 } 0°C to 10 } 60°	<1	Only a few receivers tested
9(L)	A3	Mobile	100–1000	No	Max. Mean Min.						4 3·3 2·6		1·7 1·1 0·4			1 receiver tested

(1) For 5% supply voltage variation.

TABLE III

General purpose receivers

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency-changer used		Relative frequency drift (× 10⁻⁶) at the following times (in minutes) after switching on: 1	10	30	60	120	Relative frequency variation (× 10⁻⁶) due to supply voltage variation of: 10%	20%	Relative frequency variation (× 10⁻⁶) due to temperature variation of: 1°C	For range shown	Relative frequency variation (× 10⁻⁶) due to mechanical shock	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)		(9)		(10)	(11)
1(LW)	A1 A2 A3	General purpose	1·6–30	No	Max. Mean Min.		390 180 4	223 85 2	0 0 0		176 52 6·5				140 26 1	13 receivers tested
2(LW)	A1 A2 A3	General purpose	1·6–30	Yes	Max. Mean Min.		235 124 5	130 41 1	0 0 0	86 20 1	0·6		3 2 1·5		<1 <1 <1	11 receivers tested
3(LW)	A1, A2 A3 F3	General purpose	100	No	Max. Mean Min.		135 47	39 35	0 0		10	114 3·6			14 3·5	

TABLE IV

Sound-broadcast receivers

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency-changer used		Relative frequency drift (× 10⁻⁶) at the following times (in minutes) after switching on					Relative frequency variation (× 10⁻⁶) due to supply voltage variation of:		Relative frequency variation (× 10⁻⁶) due to temperature variation of:		Relative frequency variation (× 10⁻⁶) due to mechanical shock	Remarks
						1	10	30	60	120	10%	20%	1°C	For range shown		
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)		(9)		(10)	(11)
1(LW)	A3	Sound-broadcast	0·5–1·6	No	Max. Mean Min.	1000 700 60	830 263 7	470 115 0	0 0 0	234 91 0	1100 107 30				150 38 0	Col (7): 52 receivers tested Col. (8): 48 receivers tested Col. (10): 6 receivers tested
2(LW)	A3	Sound-broadcast	1·6–30	No	Max. Mean Min.		770 241 20	320 118 3	0 0 0	575 159 57	475 89 0·6				142 30 0	Col. (7): 17 receivers tested Col. (8): 13 receivers tested Col. (10): 15 receivers tested
3(LW)	A3, F3	Sound-broadcast	30–100	No	Max. Mean Min.	857 250 26	958 226 0	335 33 0	0 0 0	150 50 0	403 130 1					Col. (7): 25 receivers tested Col. (8): 32 receivers tested

Table V

Television receiver

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency changer used		Relative frequency drift (× 10⁻⁶) at the following times (in minutes) after switching on					Relative frequency variation (× 10⁻⁶) due to supply voltage variation of:		Relative frequency variation (× 10⁻⁶) due to temperature variation of:		Relative frequency variation (× 10⁻⁶) due to mechanical shock	Remarks
						1	10	30	60	120	10%	20%	1°C	For range shown		
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)		(9)		(10)	(11)
1(LW)	A5 F3	Television	100–300	No	Max. Mean Min.	2200 555 200	360 180 80	300 113 0	0 0 0	660 300 0	1000 600 200		12(¹)		350(¹)	Only a few receivers tested

(¹) Approximate values.

Table VI

General purpose high stability receiver with compensating capacitor

Reference	Class of emission	Service	Frequency range (MHz)	Crystal-controlled frequency-changer used		Relative frequency drift (× 10⁻⁶) at the following times (in minutes) after switching on					Relative frequency variation (× 10⁻⁶) due to supply voltage variation of 10%	Relative frequency variation (× 10⁻⁶) due to temperature variation of:		Relative frequency variation (× 10⁻⁶) due to mechanical shock	Remarks
						1	10	30	60	120		1°C	For range shown		
(1)	(2)	(3)	(4)	(5)	(6)	(7)					(8)	(9)		(10)	(11)
1	A1 A2 A3 F1 F3	General purpose	24–184	No	Max. Mean Min.	100 70 15	83 50 12	45 30 7	0 0 0	30 20 6	24 16 7	11 5·5 1·5			4 receivers tested

TABLE VII

High-stability traffic receivers using combined systems

Reference	Class of emission	Service	Frequency range	Type of frequency changer used		Relative frequency drift (× 10⁻⁶) at the end of the following times in hours			Relative frequency variation (× 10⁻⁶) due to supply voltage variation of 10%		Relaive frequency variation (× 10⁻⁶) due to mechanical shock
						1	6	12			
(1)	(2)	(3)	(4)	(5)	(6)	(7)			(8)	(9)	(10)
1		General purpose	Tested at 20 MHz	Automatic correction		25·3(1)			1·8		3·5
2		General purpose	Tested at 20 MHz	Automatic correction					1·8		3
3		General purpose	Tested at 20 MHz	1st crystal oscillator(2)		11(3)			<0·3		
4		General purpose	Tested at 20 MHz	1st crystal oscillator(2)		24(1)			0·3		0·9

(1) Measurement started 5 minutes after switching on.
(2) Double frequency-change receiver: first frequency change by very stable crystal controlled oscillator; second frequency change on a much lower frequency (see Doc. II/24, Geneva, 1958).
(3) Measurement started 60 minutes after switching on (including thermostat).

RECOMMENDATION 334 *

RESPONSE OF BROADCAST AND TELEVISION RECEIVERS TO IMPULSIVE AND QUASI-IMPULSIVE INTERFERENCE **

(Question 2/II)

The C.C.I.R., (1956 – 1963)

CONSIDERING

(a) that many types of interference—e. g. from atmospheric phenomena, ignition systems and electrical equipment—cannot be considered as random noise or as simple isolated impulses, but may be regarded as " quasi-impulsive " (see Note);

(b) that the C.I.S.P.R. has produced two publications:

- Publication 1: specification for C.I.S.P.R. radio-interference measuring apparatus for the frequency range 0·15 MHz to 30 MHz ***;
- Publication 2: specification for C.I.S.P.R. radio-interference measuring apparatus for the frequency range 25 MHz to 300 MHz ***;

UNANIMOUSLY RECOMMENDS

1. that the C.C.I.R. be guided provisionally by the measuring methods of C.I.S.P.R. and their specifications for measuring apparatus;

2. that the C.I.S.P.R. radio-interference measuring apparatus be used as a guide in evaluating the parameters of quasi-impulsive interference, affecting sound and television broadcast reception.

Note. – *Quasi-impulsive noise* means interference of an intermediate type between two extreme types, that is *thermal noise* or white noise of irregular amplitude and shape with impulses following one another in such a way that their effects in the receiver more or less overlap, and *impulsive noise proper* consisting of successive impulses shorter in duration than the time constant of the receiver, separated by intervals so long that their effects do not overlap. The main categories of quasi-impulsive noise are atmospheric interference and that arising from artificial sources, such as noises produced by motors fitted with brushes, the corona effect of high voltage equipment, etc. A noise can be either impulsive or quasi-impulsive according to the time constants of the receiver affected.

* This Recommendation replaces Recommendation 159.

** See also Opinion 2, Question 2/II and Report 183-1.

*** Available from the I.E.C. Central Office, Geneva.

REPORTS OF SECTION B (RECEPTION)

REPORT 183-1 *

USABLE SENSITIVITY IN THE PRESENCE OF QUASI-IMPULSIVE INTERFERENCE

(Question 2/II, § 1)

(1959 - 1963 - 1966)

1. Introduction

As mentioned in Recommendation 334, the expression *quasi-impulsive interference* can be interpreted in different ways. In this Report, it is taken as that kind of interference which is intermediate between the two extreme cases of:

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

The two main types of quasi-impulsive interference are *atmospheric noise* and *man-made noise*, such as disturbances from switches, electric motors, radio-frequency excited arc welders, etc. The man-made noise may, for certain periods of time, occur quasi-periodically, with fairly constant shape and amplitude. Such interference requires special methods of measurement, and the calculation of its effects on the receivers is difficult.

2. Atmospheric noise

2.1 *Measurement*

Atmospheric noise has been studied for many years. A few recent papers are listed in the Bibliography below (see also Recommendation 372, Resolution 8–1, Report 322, Study Programmes 1A/III and 20A/VI). They show that it is possible, at a given time, in a given place, on a given frequency, with a given bandwidth and a given detector and recording instrument time constant, to measure and record certain characteristic quantities:

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

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

Numerous curves of such distributions have been given [1, 2, 4, 5, 7, 14, 15]. One can try to approximate them by simple mathematical laws, a few of which are listed in the attached Annex. But these laws are only approximate. The important point is that, although the Rayleigh law is more or less correct for the lower levels of natural interference (which are exceeded during most of the time), it is completely wrong for strong interference, which occurs rarely or for short periods of time; the probability of " strong quasi-impulsive noise "

* This Report was adopted unanimously.

decreases much more slowly (Fig. 1). The dynamic range of natural noise is therefore much greater than that of thermal noise. Hence, as the majority of radiocommunications require a very low error probability (e. g. 0·01 % for telegraphy), they are still appreciably disturbed by rare and very strong noise, and, at such levels, the curves show * that an increase in the signal intensity has little effect—much less than with thermal noise.

Studies carried out over many years have made it possible to assess the atmospheric noise distribution over the surface of the earth, as well as its variations with the hour of the day, season, ionospheric disturbances, etc. Changes in the distribution of amplitude, variation rate, etc., have been reported [5, 7 and Report 322], and further work is being continued.

2.2 *Influence of receiver bandwidth on:*

2.2.1 *Mean energy*

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

It can be concluded that the mean energy produced in a receiver by natural noise must be proportional to the bandwidth B; the r.m.s. voltage is therefore proportional to $\sqrt{B}$. This appears to be confirmed by general experience. But it does not necessarily follow that the other characteristic values, and ultimately the effect on the receiver, are also proportional to $\sqrt{B}$.

2.2.2 *Mean voltage*

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

- according to the U.K., if $B > 0{\cdot}3$ kHz: $B^{0\cdot33}$ to $B^{0\cdot25}$
- according to Florida University, U.S.A.: $B^{0\cdot34}$
- according to the N.B.S., U.S.A. ([1], Fig. 20): $B^{0\cdot42}$
- according to the N.B.S., the mean logarithm increases approximately with $B^{0\cdot35}$

2.2.3 *Amplitude distribution*

The influence of bandwidth on amplitude distribution can be calculated [6, 16].

2.2.4 *Harmful effect of noise*

Finally, the effect on the receiver may vary in accordance with quite a different law. Specifically, if there is a limiter, an increase in the pre-limiter bandwidth may decrease the harmful effect of noise because the limiter is presented with noise impulses of larger amplitude and smaller duration. After limiting, the noise energy is further reduced by restricting the bandwidth to that necessary for the transmission of the signal. The discriminator, if used, should not be the bandwidth limiting element but should be linear over, at least, the significant bandwidth.

3. Man-made noise

3.1 *C.I.S.P.R. studies*

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

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

Nevertheless, some of the contributions submitted contain observations and conclusions of a general nature on these types of noise and the effect they produce, which may be useful in providing a reply to Question 2/II. The comments may be summarized as follows:

3.2 *Short pulses*

Some types of man-made interference considered may be regarded as short pulses, more or less constant in amplitude (or at least, subject to no more than slight variations), repeated at a fairly regular rate governed by the nature of the interfering equipment.

The repetition rate, N, may be very low, e.g. a fraction of a hertz; or of the order of industrial frequencies, e.g. 50 or 50 Hz; or, again, higher than that, although rarely exceeding a few kHz; i.e. the passband of the receiver, B. The result is that the duration, T, of each interfering pulse is, in practice, usually very short compared with the interval between two pulses.

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

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

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

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

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

3.3 *Continuous interfering signal with rapid frequency sweep*

It has been suggested [8], that the effect of a continuous wave with a rapidly varying frequency, sweeping quickly through the passband of the receiver, may be likened to a *shock* and regarded as a short interfering signal of the type dealt with in § 3.2. This phenomenon, which is liable to arise with certain machinery using high frequencies, is worthy of further study.

3.4 *Standard interference generators*

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

3.5 *Evaluation and comparison of different interferences*

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

4. Susceptibility of radiotelegraphy receivers to noise

4.1 *Elementary considerations*

Assuming that noise is a known factor it is possible to calculate its effect upon a receiver, and, in particular, the error probability on a signal of a given type (for example, teleprinter), arriving at a fixed level. This can be done in two stages:

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

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

In synchronous working: $P = 1 - (1 - p)^5 \approx 5p$ (if *p* is small)

For a start-stop system: $P = 1 - (1 - p)^{17} \approx 17p$ (if *p* is small)

A variable signal level may then be considered. It has been found [2], that the lower the admissible error rate, the more troublesome the fading. In a specific instance, the useful field strength of the signal had to be multiplied by 1·6 for 10% error and by 5·0 for 0·1% error.

4.2 *Effects of rate of variation of noise and the signalling speed*

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

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

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

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

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

$$P' = 1 - (1 - p)^7$$
$$= 7p \text{ (if } p \text{ is small)}$$

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

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

4.3 *System performance factor*

A receiver system may be characterized (see [2], Table I), by a system performance factor *SPF*, equal to the transmission speed divided by the signal-to-noise power ratio required for a given error probability. It is conveniently expressed in decibels by:

$$SPF = 10 \log_{10} W - 20 \log_{10} (s/n)$$

where W : speed in words/minute.
s : r.m.s. signal voltage
n : r.m.s. noise voltage in an effective bandwidth of 1 kHz.

Note. – The value of the *SPF* decreases as the value of the error probabilities decreases.

It is observed that these values and their rate of decrease depend on the receiver, the code used and the type of noise. For example, for a certain type of automatic frequency-shift teleprinter receiver, the maximum value of the *SPF* is 17·8 dB and 14·8 dB for 10% error, with thermal and atmospheric noise respectively. If the admissible error-rate is reduced to 0·1%, the *SPF* only decreases from 17·8 to 15·8 dB in the presence of thermal noise, while the decrease is much more marked in the presence of atmospheric noise (from 14·8 to 6·8 dB). In other words, to reduce the error probability from 10% to 0·1%, it suffices to increase the signal by 2 dB in the first case, while in the second case, it must be increased by 8 dB.

The part played by *frequency shift* and its optimum value [2], might likewise prove to be important. In manual Morse telegraphy with aural reception, for an accepted letter error rate of 10%, the performance factor is 12·8 dB for thermal noise, and ranges from 13 to 22 dB for atmospheric noise. The presence of a human operator, however, makes it very difficult to reduce the error-rate to below 1%.

5. Reduction of susceptibility to noise by design of receivers

Certain receiver design techniques have been found useful in reducing the effects of noise. See Docs. II/1 (U.S.A.) and II/14 (U.S.S.R.), Geneva, 1965. They may be described as follows:

5.1 *Large dynamic range and fast recovery from overload*

In certain forms of man-made noise the durations of the interference pulses are very short compared to the intervals between pulses. Receivers subject to such interference may provide acceptable reception, even though the instantaneous amplitude of the pulses greatly exceeds the amplitude of the wanted signal, if care is taken in the design of the receiver to insure linear operation over a large dynamic range of signal levels. If the pulse signals may exceed the linear dynamic range of the receiver, the design of the receiver should be such that there is a rapid recovery from overload conditions after each pulse.

5.2 *Noise limiting*

The use of noise limiters in receivers is beneficial in many cases of interference from man-made noise. Such limiters are designed to prevent the radio-frequency, intermediate frequency, audio or video signal level (resulting from the combination of wanted signal and interfering pulse) from exceeding a certain level. This level may be set just above the highest level reached in the modulation of the wanted signal. Care is taken to insure that the noise limiter recovers immediately after each interference pulse.

5.3 *Optimum disposition of selectivity and limiting*

Effective attenuation of interference can be achieved in receivers which have the following structure: a linear preamplifier with passband considerably in excess of that required, followed by a limiter, and an amplifier with the narrowest possible passband [17].

5.4 *Noise blanking*

In cases of locally generated interference, e.g. automobile ignition interference to a receiver in the same automobile, or operation of a receiver near a pulsed transmitter, the use of " interference blanking " may be very beneficial. This technique involves the momentary switching-off of the receiver by a negative pulse applied to the grid of a radio-frequency, or early intermediate-frequency amplifier at the time of occurrence of an interference pulse. The triggering of the negative pulse may be by means of an electrical connection to the source of interference, or it may be by the use of an auxiliary wide-band receiver of low sensitivity, receptive to the interference. It may be necessary to introduce a delay line in the wanted signal path in the receiver, or its antenna circuit, to allow the receiver switch-off to occur before the interference transient reaches the gate.

5.5 *Time-sampled a. g. c. or other receiver functions*

In receiving systems, quasi-impulsive interference may disturb certain auxiliary functions, such as automatic gain control or, in television, horizontal or vertical-scan synchronization. Because these auxiliary functions do not require continuous information from the wanted signal, a very considerable reduction of the objectionable effects of quasi-impulsive interference can be obtained by the use of the time-sampled operation of the auxiliary functions of the receiver. Thus, in television receivers, the use of automatic gain control and scan-synchronizing circuits, which receive corrective information from the wanted signal only at certain periodic intervals (e. g. the sync. pulses), affords a great reduction in the objectionability of quasi-impulsive interference because most of the interference pulses occur at times when the automatic gain control and scan-synchronising circuits of the receiver are not affected.

5.6 *Noise compensation*

In many cases, quasi-impulsive interference may be received in a frequency band close to the wanted signal band, and not occupied by a radio signal. After amplification, this may be used for interference compensation in the basic receiver channel. Predetection or post-detection compensation may be carried out in the linear part of the receiver [18, 19].

5.7 *Time diversity*

The effects of atmospheric noise have been found to have a duration of less than 1·5 s. Similarly, other forms of quasi-impulsive interference (and incidentally multipath delay distortion), have a duration of less than one second. Therefore, the application of time-diversity means to telegraph circuits, with one path delayed about two seconds, has proved to be very effective in the reduction of error-rates without the requirement of a reciprocal return circuit.

6. Summary

On the basis of the above considerations, the following partial reply may be given to § 1 of Question 2/II:

The usable sensitivity of receivers may be reduced by quasi-impulsive interference in any service, depending on local conditions and the frequency range used [12].

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

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

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

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

Sets of figures corresponding to different error probabilities, e. g. from say 10% to 0·01%, would serve a useful purpose.

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

The maximum admissible interference level can only properly be calculated after performing the analysis described in the preceding paragraph.

The impulse-limited sensitivity will be a function of:

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

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

Certain receiver design techniques have been found to be effective in reducing susceptibility to man-made noise. These include provision of large dynamic range and fast recovery from overloads, noise limiting, optimum disposition of selectivity and limiting portions of the receiver, noise blanking, time sampling and noise compensation.

Time diversity has been found useful in reducing the effects of atmospheric noise.

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ANNEX

FORMULAE FOR AMPLITUDE DISTRIBUTION

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

Let V be the envelope voltage,

V_m its median value and

$\bar{V}$ its average value.

1. Rayleigh law

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

$$Q(V) = 1 - \exp(-0{\cdot}693\, V^2/V_m^2)$$

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

2. Log-normal distribution

Putting $x = \log (V/\overline{V})$, the probability of an amplitude comprised between V and $(V + dV)$ is:

$$q\ (V)\ dV = \frac{1}{\sqrt{\pi}} \exp\ (-\ x^2)\ dx$$

and the overall probability of an amplitude greater than V is

$$Q\ (V) = \int_V^\infty q\ (V)\ dV$$

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

3. Law

$$Q\ (V) = [1 + (V/V_m)^q]^{-1}$$

q being an experimental constant.

4. Law

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

where $V = a_1 y + a_2 y^{(b+1)/2} + a_3 y^b$

and $b = 0{\cdot}6\ [20 \log_{10} (V_{rms}/\overline{V})]$

Representation of amplitude distributions

Observed amplitude distributions generally do not follow simple laws such as those given above. It has been found that a typical distribution can be represented on suitable graph coordinates by a curve formed by two straight lines joined by an arc of a circle. An empirically-devised graphical method has been shown for obtaining an amplitude-probability distribution of this form from three measured statistical moments of the sample of noise: average power, average voltage, and average logarithm of the voltage [14, 15, 16].

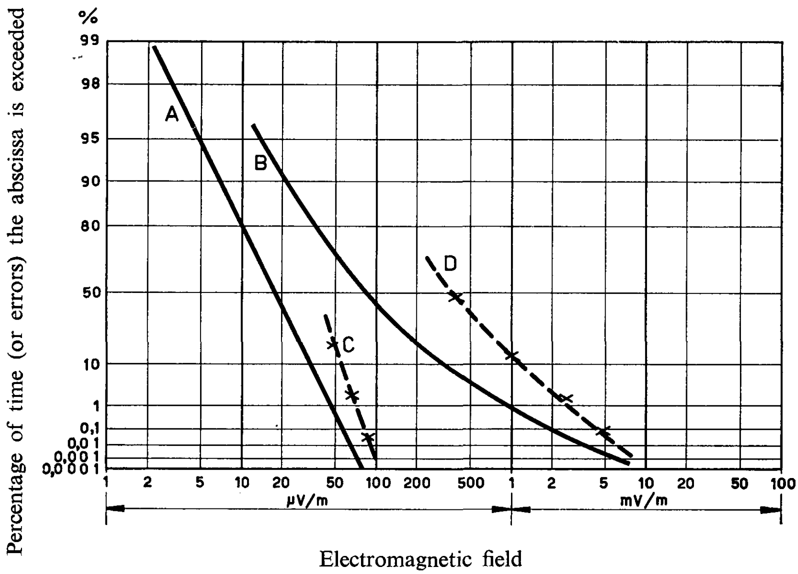


FIGURE 1

Comparison of thermal and atmospheric noise

A: thermal noise envelope
B: atmospheric noise envelope
C: errors due to thermal noise
D: errors due to atmospheric noise

REPORT 184 *

CHOICE OF INTERMEDIATE-FREQUENCY AND PROTECTION AGAINST UNWANTED RESPONSES OF SUPERHETERODYNE RECEIVERS

(Question 171)

(1956 – 1959 – 1963)

1. The following statements can be made as a result of studies on this subject:

1.1 The principal factors contributing to the production of unwanted responses of superheterodyne receivers are inadequate image and intermediate-frequency response ratios and the generation of intermediate-frequency and frequency-change oscillator harmonics.

Measured values of the unwanted responses occurring in receivers of various types are given in Docs. 6 and 157, Warsaw, 1956, Docs. II/1, II/4, II/13 and II/20, Geneva, 1958 and Doc. 138, Los Angeles, 1959.

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

1.3 For domestic frequency-modulation receivers, the intermediate-frequency of 10·7 MHz normally used, is satisfactory, provided that radiation by the receiver at the intermediate-frequency and its harmonics and at the frequency of the local oscillator and its harmonics, is sufficiently reduced.

1.4 For monochrome television receivers, working in Bands I and III, there seems to be a genera trend towards a national standardization of the intermediate-frequency channel. As several television systems are in use, and since, for any one system, there are different channel allocations in different countries, it seems impossible to propose only one preferred intermediate-frequency. Preferred values of intermediate-frequencies in different countries for monochrome television receivers are shown in Table I.

Note. – This Table includes data provided at Geneva, 1958, Los Angeles, 1959, and Geneva, 1963, and will be completed in the future.

With the exception of some particular geographical regions, taking into account the limited range for VHF and UHF transmitters, the general situation does not seem to be critical. No new points of view are expected with respect to the choice of intermediate frequency. Anyhow, other technical means are already applied and used in the common techniques to avoid external and internal interference, so that practical results are quite

* This Report, which replaces Report 98, was adopted unanimously.

TABLE I

Number of lines per picture frame	Country	Channel limits at intermediate frequency (MHz)	Intermediate frequency	
			Sound channel f_s (MHz)	Video-channel f_v (MHz)
405	United Kingdom	33·4–38·4	38·15	34·65
525	United States	41–47 (1)	41·25	45·75
	Japan	22–28 (2)	22·25	26·75
625	Spain Netherlands Federal Republic of Germany Switzerland	33·15–40·15	33·4	38·9
	Italy	40–47 (2)	40·25	45·75
	U.S.S.R.	27·5–35·5	27·75	34·25
	France (bands IV, V)	31·0–39·5	39·2	32·7
819	France (band III)	25·1–39·5	39·2	28·05

(1) According to Electronic Industries Association Standard Rec. No. 109 C.
(2) Protected band.

satisfactory. It seems, therefore, reasonable to finish the studies for these types of receiver as given under §§ 1.2, 1.3 and 1.4.

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

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

1.7 For mobile receivers, it is difficult to relate the choice of intermediate-frequency to geographical locations, since such receivers may be required to operate in the vicinity of any one of a large number of transmitters. Double-superheterodyne reception is often employed in mobile receivers operating in the VHF range to obtain good image rejection.

1.8 For maritime mobile receivers, the most unfavourable areas are the coastal zones close to high-power broadcasting stations or coast stations, if the fundamental or a harmonic of the frequency of such a station is close to the intermediate-frequency of the receiver. The results of watches in the frequency band 530–700 kHz show that the intermediate-frequencies chosen for this service are often very close to the fundamental frequencies of high power (100 kW or more) broadcasting transmitters. In certain maritime areas of high density traffic, the interference could be serious if it occurred during distress traffic and if the intermediate-frequency rejection were inadequate.

For frequencies below 30 MHz, the intermediate-frequencies used in receivers depend on the signal frequency and the desired image rejection. For receivers required to operate in the 500 kHz maritime band, the commonly used intermediate-frequencies of 420 to 475 kHz are clearly unsuitable. There, higher values, e. g. 530 to 700 kHz are used. For single-superheterodyne receivers, giving continuous coverage of a wide range of frequency, it is necessary to change the intermediate-frequency to suit the signal-frequency range in use. The signal-frequency range, which contains the higher intermediate-frequency, is received by using the lower intermediate-frequency and vice-versa. The higher intermediate-frequency is usually above 400 kHz, to provide the image rejection needed in the high-frequency ranges, and the lower intermediate-frequency is usually about 100 kHz.

Reception by telegraph receivers of insufficient selectivity can be improved by the addition of audio-frequency selectivity, e.g. selective head-phones (see Doc. II/25 (Italy), Geneva, 1962).

It may be convenient to use double-superheterodyne reception for the HF bands, as well as for the band containing the lower intermediate-frequency. In a double-superheterodyne receiver, the first intermediate-frequency can, with advantage to image rejection, be chosen between 1 and 1·5 MHz.

Maritime mobile receivers for the VHF band are usually of the double-superheterodyne type with a first intermediate-frequency of about 10 MHz; the second intermediate-frequency is often in the frequency range 400 to 500 kHz. Interference has been known to occur when a transmitter in this band was in operation on the same ship as the VHF receiver. The same problem arises when the second intermediate-frequency is in the 2 MHz band, which is used by ships for radiotelephony. It is recommended that the bands 405 to 535 kHz and 1605 to 2850 kHz should be avoided when choosing the second intermediate-frequency for such receivers.

The values for minimum intermediate-frequency rejection ratio for receivers in the maritime mobile service are given in Table II:

Minimum intermediate-frequency rejection ratio (dB)		
General purpose receivers 15 kHz to 25 MHz	Radiotelephone equipment 1600-3700 kHz	VHF receivers at about 160 MHz
60(1)	60(2)	90

(1) In the United Kingdom, an intermediate-frequency response ratio of 90 dB is specified when the intermediate-frequency lies between 140 and 1600 kHz.

(2) In the United Kingdom, an intermediate-frequency response ratio of 80 dB is specified when the intermediate-frequency lies between 140 and 1600 kHz.

If it is necessary to transmit and receive simultaneously, under conditions such that the frequency of a transmitter used for one link falls in or near the intermediate-frequency band of a receiver used for another link, additional intermediate-frequency rejection may be necessary.

REPORT 185–1 *

SELECTIVITY OF RECEIVERS

(Question 3/II)

(1963 – 1966)

1. In the preparatory documents of the Interim Meeting of Study Group II, Geneva, 1962, a limited amount of data is to be found for which there is no column in the Tables of the corresponding Recommendations.

 Rather than alter the existing lay-out of the Tables, Study Group II has decided to submit these data in the form of a Report.

 Table I gives the values for higher order intermodulation products, contained in Doc. II/23 (Japan), Geneva, 1962.

 Table II gives the values of attenuation, for the frequency indicated, contained in Doc. II/30 (United Kingdom), Geneva, 1962.

 Table III and Figs. 1 and 2, respectively, give the values of effective selectivity and radio-frequency characteristics of a new type of transistorized HF telephone receiver for fixed services; these values are compared with those of a conventional vacuum-tube receiver (Doc. II/8 (Japan), 1963–1966). The purpose of the design of this receiver is to improve the selectivity by using crystal filters in the input stage.

2. In Docs. II/54 and II/56 (Italy), 1963–1966, some criteria are given to improve the multiple signal selectivity characteristics of Band 8 FM-receivers and Band 7 fixed service receivers.

* This Report was adopted unanimously.

TABLE I

Class of emission	Service	Frequency range (MHz)	F_d (MHz)		Intermodulation — Level of unwanted signals (dB rel. 1 µV) for the level of the wanted signal given below																				Remarks
					$F_n'+F_n'' = F_{im}$		$F_n'-F_n'' = F_{im}$		$2F_n'-F_n'' = F_d$					$3F_n'-F_n'' = F_d$		$2(F_n'-F_n'') = F_{if}$		$3F_n'-2F_n'' = F_d$					$4F_n'-3F_n'' = F_d$		
					a(1)	20	b(1)	20	c(1)	20	40	60	80	d(1)	20	e(1)	20	f(1)	20	40	60	80	g(1)	20	
(1)	(2)	(3)	(4)	(5)	(6)																				(7)
A3B	Fixed	from 5 to 22	9·75	Max. Mean Min.	9·8; 1·95	>104 >104 >104	21·55; 9·8	>104 >104 >104	9·8; 9·85	64 57 49				9·8; 19·65	>104 > 97 83	9·8; 9·3	>104 > 94 84	9·8; 9·825	73 64 55				10·35; 10·55	>104 >104 >104	3 receivers tested (IF 1 MHz)
		from 4 to 23	10	Max. Mean Min.	10·1; 5·5	>104 >104 >104	25·7; 10·1	>104 >104 >104	10·1; 10·2	68 65 60				10·1; 20·3	>104 > 95 77	11·5; 10·1	>104 >104 >104	10·1; 10·15	>104 > 93 72				10·3; 10·4	>104 > 95 77	3 receivers tested (IF 2·8 MHz)
		from 4 to 28	10	Max. Mean Min.			23·8; 10·1	>104 >104 >104	10·1; 10·2	68 68 68				10·1; 20·3	>104 > 97 89	11·025; 10·1	>104 >104 >104	10·1; 10·15	>104 > 92 79				10·3; 10·4	>104 > 96 88	2 receivers tested (IF 1·85 MHz)
A3	Fixed	from 5 to 22	10	Max. Mean Min.	10·1; 1·9	>104 >104 >104	22·1; 10·1	>104 >104 >104	10·1; 10·2	79 78 77				10·1; 20·3	>104 >104 >104	10·6; 10·1	>104 >104 >104	10·1; 10·15	>104 >104 >104				10·3; 10·4	>104 >104 >104	3 receivers tested (IF 1 MHz)
A1	General purpose	from 5 to 22	9		9·1; 0·81	> 95	19·01; 9·1	95	9·05; 9·1	65	74	79	86	6·03; 9·09	78	9·0275; 8·8	56	9·1; 9·15	68	73	77	81			1 receiver tested (IF 445 kHz)

(1) Indicates frequencies of two unwanted signals: F_n' and F_n''.

TABLE II

Single-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency of wanted signal (MHz)	RF & IF passband (kHz)	Attenuation slope for attenuation A db rel. maximum response (dBkHz)				Ultimate slope in dB octave	Spurious response ratio (dB) when input frequency[1] (MHz) is:						Remarks
				Attenuation A dB					F_{if}	$F_o \pm F_{if}$ (Image)	$2F_o+F_{if}$	$\frac{2F_o+F_{if}}{2}$	Other relationship		
				26	46	66	86						Ratio	Relationship	
(1)	(2)	(3)	(4)	(5)				(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
F3	Fixed 30–300 MHz	165·7	46	2·6	3·8	4·4	4·8	140	92	86	>110	95	86	$\frac{2}{3}F_{o_1}+F_{if_2}$	Two double superheterodyne receivers of the same type 1st conversion local frequency F_{o1} 1st crystal oscillator operates at $\frac{1}{8}F_{o1}$ 2nd intermediate frequency F_{if_2}
													94	$\frac{4}{3}F_{o_1}+F_{if_2}$	
													106	$\frac{\frac{4}{3}F_{o_1}+F_{if_2}}{2}$	
													86	$F_{o_1}+F_{o_2}+F_{if_2}$ (2)	
		166·75	46	2·6	3·8	4·4	4·8		80	79	>110	88	97	$\frac{2}{3}F_{o_1}+F_{if_2}$	
													>110	$\frac{4}{3}F_{o_1}+F_{if_2}$	
													>110	$\frac{\frac{4}{3}F_{o_1}+F_{if_2}}{2}$	
													76	$F_{o_1}+F_{o_2}+F_{if_2}$ (2)	

(1) F_o : Frequency of first frequency-changing oscillator; F_{if} : First intermediate-frequency.
(2) Image frequency of second frequency-change.

TABLE III

Fixed service telephony receiver, bands 4 to 28 MHz

Characteristics		Telephony, For public network A 3		
		Transistor type(1) with RF crystal filter		Vacuum-tube type(2)
Wanted signal-frequency (MHz)		F_o = 11·1625		F_o = 11·15
Two-signal selectivity	B_1 (kHz)	10	20	20
	B_2	68	>118	95·8
	B_3	74	>118	110
	B_4	78	>118	115·6
	B_5	79	>118	>118
	B_6	67	99	>94
Three-signal selectivity	C_1 (MHz)	11·1625		11·15
	C_5	>103		>97·6
	C_6	>103		>105·6
	C_7	>103		106·0
	C_8	>103		85
	C_9	>103		95·3
	C_{10}	>103		102·7
	C_{11}	>103		67
	C_{12}	>103		71
	C_{13}	>103		87
	C_{14}	>103		71·9
	C_{15}	>103		79·4
	C_{16}	>103		85·9

(1) The same method of measurement as indicated in Study Programme 11A/II was used. The frequencies of the wanted signal C_1 and the unwanted signal from C_5 to C_{16} are shown in the Table below.

	$F_n'-F_n'' = F_{tf}$		$F_n'+F_n'' = F_d$		$F_n' - F_n'' = F_o$		$2F_n' - F_n'' = F_o$	
C_1	F_n'	F_n''	F_n'	F_n''	F_n'	F_n''	F_n	F_n''
11·1625	13·0725	11·2225	5·5375	5·625	22·8725	11·210	11·21625	11·270

(2) The results of measurement indicated here are taken from Doc. II/9 (Japan), 1963-1966.

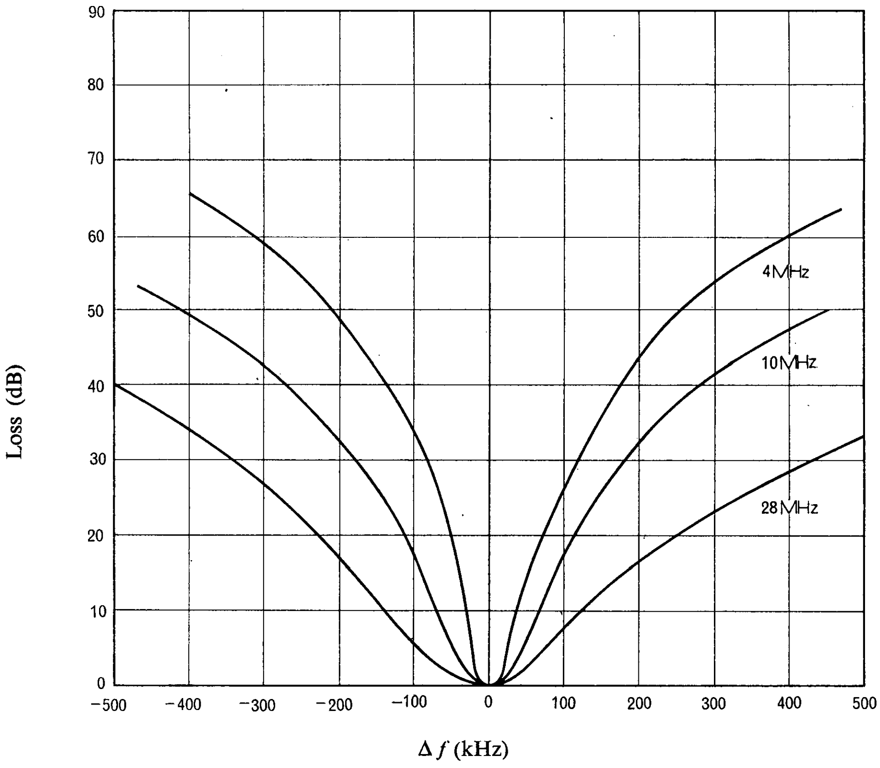
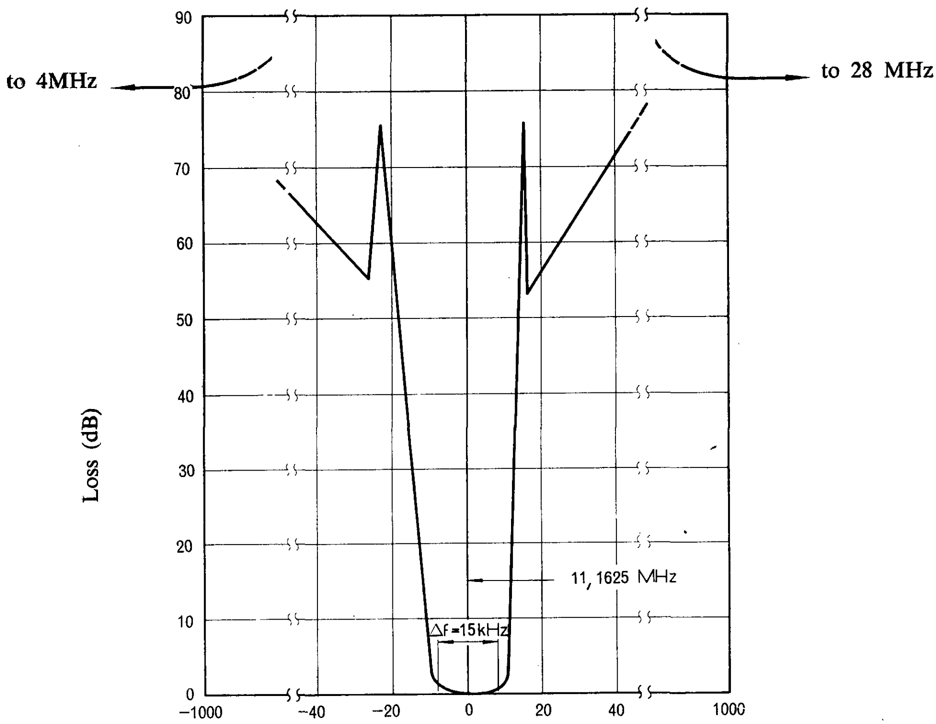


FIGURE 1

Radio-frequency characteristics of a typical receiver



Δ *f* (kHz)

FIGURE 2

Radio-frequency characteristics of a transistorized receiver with RF crystal filter

REPORT 186–1 *

MULTIPLE-SIGNAL METHODS OF MEASURING SELECTIVITY

(Question 3/II)

(1963 – 1966)

1. The single-signal selectivity curve of a receiver is not sufficient to characterize fully the protection enjoyed by the receiver against unwanted signals. The non-linearity of the receiver circuits influences the selectivity when interfering signals of sufficient strength are received (for instance in the mobile services). In Recommendation 332–1, § 6, it is proposed that, under such circumstances, the selectivity of the receivers should be measured as the effective selectivity by means of two or more signals applied to the input of the receiver. The ratio of the wanted-to-unwanted signals must be taken into account as an important parameter.

2. Measurements of selectivity with two signals have been reported in Docs. II/1 (Denmark), II/11 (U.S.S.R.), and II/21 (Belgium), Geneva, 1962, one being the wanted FM signal situated in the channel to which the receiver is tuned, the other being the signal that causes interference.

   In the methods described in Docs. II/1 and II/21, Geneva, 1962, first the voltage for 30% modulation of the wanted signal is measured at the output of the FM receiver without the interfering signal, and then the interfering signal is applied. The strength of the interfering signal is adjusted to such a level that the post-detector interference reaches a prescribed level (usually 20 dB below the wanted signal level). The signal-to-interference ratio at the receiver input is then measured. This is repeated for several frequency separations of the wanted and unwanted signal to obtain the effective selectivity curve.

   In Doc. II/11 (U.S.S.R.), Geneva, 1962, both wanted and unwanted signals are frequency-modulated by a frequency of 1 kHz, the modulations of both having the same phase. The selectivity is measured for a prescribed increase of the factor of non-linear distortion at the receiver output, caused by the unwanted signal. An increase of non-linear distortion up to 20% is used. It has been observed, however, that the value of the non-linear distortion factor rapidly increases when the unwanted signal increases over a certain threshold. Therefore, the choice of the increase of this non-linear distortion is somewhat arbitrary and may have values other than 20%.

3. Other measurements using two signals have been reported in Doc. II/23 (Japan), Geneva, 1962, concerning receivers for classes of emissions A3B, A3 and A1. One of the unwanted signals was chosen close to the desired channel.

   Two further measuring methods to be used for F3 receivers are mentioned in Doc. II/22 (Federal Republic of Germany), 1963–1966. The first one uses an *unmodulated* wanted signal, whereas the second method makes use of a *modulated* signal in combination with a sharp stop filter at the receiver output tuned to the wanted audio-frequency output signal. Both methods lead to practically the same results.

4. Intermodulation measurements with three signals have been reported in Doc. II/10 (Federal Republic of Germany), Geneva, 1962. In this document, it is mentioned that 20% intermodulation distortion is measured at the receiver output with a time probability of 1 in 1000. The frequencies of the two interfering transmissions have been chosen such that combination frequencies were obtained to which the receiver is particularly susceptible. The measurements were made on receivers for classes of emission F1, and A3B.

* This Report was adopted unanimously.

5. For measurements of the *wanted-to-interfering signal ratios at radio-frequencies*, as defined in Recommendation 447 (agreed values of the above lead to radio-frequency protection ratios), special methods are necessary. Although they are two-signal methods, they cover both linear and non-linear properties of the receiver. An appropriate measuring technique for amplitude-modulation broadcast receivers is mentioned in Report 399 and described in detail in Doc. II/28 (E.B.U.), 1963–1966, and in [1].

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REPORT 187 *

PROTECTION AGAINST INTERFERENCE BETWEEN KEYED SIGNALS

(Study Programme 10A/II)

(1963)

Tests have been carried out in the Federal Republic of Germany to determine the effect exerted by an interfering transmission of keyed signals on a wanted transmission also of keyed signals. For reasons connected with the design of the apparatus used, the tests were restricted to class of emission F1 and a modulation rate of 50 bauds in the wanted channel, and to the following signal shapes; rectangular, trapezoidal, rounded trapezoidal and approximately sinusoidal. In each instance, the frequency separation which gave a relative error-rate of 1×10^{-4} in the wanted signals, when in the presence of keyed interference, was determined. The parameters chosen were the signal shape and the ratio of the wanted signal power to that of the interfering signal. Two different types of heterodyne receivers were used, for short waves and of medium quality (general purpose receivers), that is, one receiver with single frequency-change (type A), and one with double frequency-change (type B). In both types of receiver the discriminator was followed by a low-pass filter, and a stage for squaring the signals.

1. Test equipment

Two transmitters, one for the wanted keyed signal and one for the interfering keyed signal, both with class of emission F1, were connected through a decoupling network to the input of a radio receiver, at the output of which a teleprinter distortion indicator was connected. This indicator allows the determination of the probability with which a certain given degree of distortion in the telegraph signals is reached or exceeded. A more detailed description of this apparatus is given in [1]. Both the wanted-signal transmitter and the interfering-signal transmitter could be keyed by rectangular signals at a modulation rate of 50 bauds, furnished by an electronic signal generator. Moreover, when using these test generators, it is possible, even when using sinusoidal keying signals (suitable low-frequency oscillator),

* This Report was adopted unanimously.

to vary the modulation of the radio-frequency signal, from a shape approximating sinusoidal to a rectangular form, by corresponding modulation of the test generators. The frequency spacing between the wanted signal and the interfering signal was found in each case by measuring the difference frequency with a frequency indicator.

2. Test parameters

2.1 *Signal shape:* The tests were made with five different signal shapes, which were designated arbitrarily, and whose build-up and decay time τ was determined from oscillograms:

Rectangular	$\tau \approx 0\%$	relative to the total nominal duration of the element.
Rounded rectangular	$\tau = 4{\cdot}9\%$	
Trapezoidal	$\tau = 14{\cdot}2\%$	
Rounded trapezoidal	$\tau = 19{\cdot}4\%$	
Approximately sinusoidal	$\tau = 51{\cdot}3\%$	

2.2 *Frequency separation:* Since, in current receivers, the possibility of varying the bandwidth of the receiver is limited to a few values, the frequency separation was so chosen that the necessary spectrum of the wanted signals was either less, equal to, or greater than the bandwidth of the receiver adjusted for the given case.

2.3 *Modulation rate:* Since the telegraph distortion indicator was only capable of operation at a modulation rate of 50 bauds, this speed was chosen for the wanted signal. To avoid beats, the interfering signal generator was used, in general, at a modulation rate of 80 bauds.

2.4 *Bandwidth:* In each instance, the receiver bandwidths were so chosen that the necessary bandwidth (determined in accordance with C.C.I.R. Recommendation 328–1), was either equal to, less, or greater than the receiver bandwidth (see also § 2.2).

2.5 *Slopes at the sides of the filter passbands:* The slope at the side of the passband was 20 dB per 1 kHz for the receiver type A, and 80 dB per 1 kHz for the receiver type B.

2.6 *Input voltage to the receiver:* For both types of receiver, the same r.m.s. input voltage of 2·5 μV was chosen. The deciding factor in the choice was that the test results must be affected by the keyed signals alone, and that no effects due to noise could be allowed. The signal/noise ratio, measured at the output of the IF stage of the receiver was, with this value of input voltage, between 24 and 28 dB, depending on the bandwidth of the receiver.

2.7 *Frequency of the wanted signals:* For practical reasons, a low value in the HF band was chosen (4 MHz), because the instability of the apparatus has less effect at this frequency.

2.8 *Limiting value of reference distortion:* A margin of 35% was assumed for the teleprinters (C.C.I.T., 1953). In the present instance, a degree of reference distortion of 40% being reached and exceeded was chosen as a criterion of frequency errors.

3. Test results

With the interfering transmitter disconnected, the smallest value of the signal-to-noise ratio that would avoid errors due to noise was determined. This value was found to be some 16 dB. In consequence, an input voltage of 2·5 μV was chosen for the tests, which gave a signal-to-noise ratio of at least 24 dB (see also § 2.6).

During the later stages of the tests, the bandwidth of the emission was chosen, in accordance with §§ 2.2 and 2.4, to be such that in each case it was either smaller, equal to or larger than the bandwidth of the receiver. Another parameter was the ratio of the wanted-to-interfering-signal powers, for which, in each case, three different values were chosen. The use of these parameters permitted the relative frequency, with which the value of 40% distortion was exceeded, to be determined as a function of the frequency spacing between the wanted and the interfering emissions for each case. In addition, the signal shape of both the wanted and the interfering keying signals was varied as in § 2.1. A series of curves resulted, of

TABLE I *

Receiver type A. Slope at the edges of the passband – 20 dB *per 1* kHz

Signal shape: Wanted	Signal shape: Interfering	N'	D (Hz)	B_n (Hz)	B_r (Hz)	Δ_f (Hz)	Remarks
a	a b c d	1/1	210	545	1000	380 370 365 355	$B_n < B_r$
	a b c d	1/3	210	545	1000	580 565 555 545	
	a b c d	1/10	210	545	1000	830 820 810 800	
b	a d	1/1	210	545	1000	400 350	$B_n < B_r$
	a d	1/3	210	545	1000	615 570	
	a d	1/10	210	545	1000	880 825	
c	a d	1/1	210	545	1000	440 395	$B_n < B_r$
	a d	1/3	210	545	1000	655 620	
	a d	1/10	210	545	1000	900 870	
d	a d	1/1	210	545	1000	460 430	$B_n < B_r$
	a d	1/3	210	545	1000	835 795	
	a d	1/10	210	545	1000	1100 1055	
a	a d	1/10	440	1005	1000	1215 1150	$B_n \approx B_r$
a	a d	1/10	545	1215	1000	1775 1725	$B_n > B_r$

* D : Frequency shift (Hz)
B_n : Necessary bandwidth in accordance with Recommendation 328-1 (Hz)
B_r : Receiver bandwidth (Hz)
N' : (N_d/N_n) = Power ratio between the wanted and interfering signals
a : rectangular
b : trapezoidal
c : rounded trapezoidal
d : approximately sinusoidal

TABLE II *

Receiver type B. Slope at the edges of the passband – 80 dB per 1 kHz

Signal shape		N'	D	B_n	B_r	Δ_f	Remarks
Wanted	Interfering	(dB)	(Hz)	(Hz)	(Hz)	(Hz)	
a	a d	0	185	495	880	390 345	$B_n < B_r$
	a d	− 6	185	495	880	625 580	
	a d	−30	185	495	880	990 925	
a	a d	0	170	465	450	370 320	$B_n \approx B_r$
	a d	− 6	170	465	450	615 565	
	a d	−30	170	465	450	890 845	
c	a d	0	170	465	450	365 305	$B_n \approx B_r$
	a d	− 6	170	465	450	605 555	
	a d	−30	170	465	450	925 870	
d	a d	0	170	465	450	420 370	$B_n \approx B_r$
	a d	− 6	170	465	450	660 630	
	a d	−30	170	465	450	1040 975	
a	a d	−30	115	355	450	880 830	$B_n < B_r$
d	a d	−30	115	355	450	985 940	
a	a d	−30	210	545	450	1045 1000	$B_n > B_r$

* D : Frequency shift (Hz)
B_n : Necessary bandwidth in accordance with Recommendation 328-1. (Hz)
B_r : Receiver bandwidth (Hz)
N' : (N_d/N_n) = Power ratio between the wanted and interfering signals.
a : rectangular
b : trapezoidal
c : rounded trapezoidal
d : approximately sinusoidal.

which the attached Fig. 1 is an example. The example only shows the curves for the two extreme forms of signal shape—sinusoidal and rectangular. The curves for the other signal shapes lie between these two extremes depending on the degree of rounding.

The two Tables attached show the values of the relative frequency 1×10^{-4} found from the curves, with the values of frequency spacing relating to them, for the different parameters. Table I refers to receiver type A, whose slope at the edges of the passband is about 20 dB per 1 kHz. As the other parameter, the following ratios of wanted-to-interfering-signal power were chosen: —1/1 (0 dB), 1/3 (—4·7 dB), 1/10 (—10 dB). Table II refers to receiver type B, of higher quality, in which the slope at the sides of the passband is about 80 dB per 1 kHz. As a result of this steeper slope, the following ratios between the wanted and interfering signal powers were chosen: 0 dB, —6 dB and 30 dB. (Compare with the Table relating to Study Programme 1A/III).

4. Discussion of the experimental results

As is shown by Fig. 1, the increase in errors, resulting from a reduction in frequency separation between the wanted and the interfering signals, is very rapid. This behaviour may be explained by the type of keying circuits used in the receivers, which regenerate the signals and merely take note of the passages of the signal through the zero amplitude.

If one examines the results as a whole, one may conclude that, from the point of view of the smallest possible frequency spacing between a transmitter of a wanted signal and that of an interfering transmission, the rectangular signals are equally unfavourable, by reason of the wide spectrum of the interfering signals, as are completely rounded signals, by reason of their greater susceptibility to interference. For the two receivers tested, a good compromise was found between bandwidth economy and the quality of transmission, in a signal from the transmitter with a build-up time of about 10%. This value does not differ significantly from the value of 8% indicated in Recommendation 328-1.

Since only two types of receiver were available, the results cannot be generalized.

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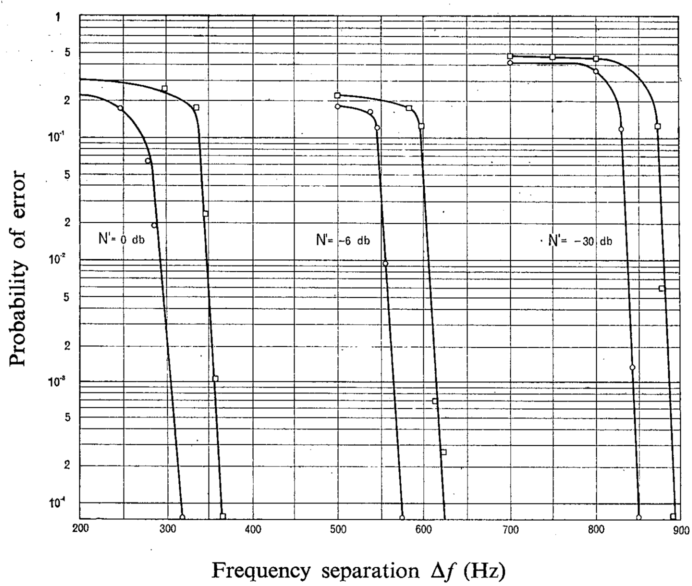

FIGURE 1

Relative frequency with which the value of 40% distortion is exceeded as a function of the frequency spacing between the transmitter of the wanted signals and that of the interfering signals, for wanted signals of rectangular form

○ Interfering signals of approximately sinusoidal waveform
□ Interfering signals of rectangular waveform

REPORT 188-1 *

CRITERIA FOR RECEIVER TUNING

Criteria to be used in measurements of tuning stability

(Question 5/II, § 1)

(1963 – 1966)

1. General

The effects of receiver frequency instability can be classified under two headings:

– reduction of protection against adjacent-channel transmissions, and
– impairment in the reproduction of the modulation of the desired signal.

This Report deals with, and the criteria given below are all based on, the second consideration.

* This Report was adopted unanimously.

2. Tuning criteria for broadcast sound and television receivers

2.1 *I.E.C. standards*

Suggested criteria are given below, in accordance with which receivers of various categories can be said to be tuned. It is worth recording that this question has been examined in detail by Sub-Committee 12.A of the I.E.C. Consequently, these criteria have been framed to line up broadly with I.E.C. documents for amplitude-modulation *, frequency-modulation * and monochrome television receivers.

2.2 *Receivers for amplitude-modulation sound broadcast (A3)*

A receiver can be accurately tuned by adjusting the tuning control for:

- the maximum indication of the tuning indicator,
- the maximum audio-frequency output power,
- the minimum audio-frequency distortion.

2.2.1 Tuning indicator: in addition to it, an external measuring instrument may be used.

2.2.2 Maximum audio-frequency output power, i. e. determination of the lowest possible radio-frequency input signal level at which an arbitrary power can be obtained, or determination of the lowest possible setting of the volume control for that power.

This method can be applied where the response has a single symmetrical peak. Otherwise, a method formerly recommended by the I.E.C. can be used:

The receiver is tuned to a signal modulated 400 Hz (or other low frequency), by setting the tuning control so that the desired output level is reached at the desired input level with the lowest possible setting of the volume control of the receiver. Next, the modulation frequency is increased until the output power has dropped by approximately 14 dB or to about 1/25, the depth of the modulation being kept at a constant value. After this, the tuning control is re-adjusted slightly until a minimum of output power is obtained.

2.2.3 Minimum distortion in the audio-frequency output. This distortion might be harmonic distortion or distortion of the amplitude/frequency characteristic, according to circumstances.

The relevance of a tuning criterion can be dependent on the level of input signal concerned. For example, with a weak signal, input criterion § 2.2.2 will almost certainly be applicable, whilst for strong signals §§ 2.2.3 or 2.2.1 will be used.

Reference: § 4.7 of I.E.C. Publication 69.

2.3 *Receivers for frequency-modulation sound broadcasting (F3)*

The criteria in this case are:

2.3.1 adjustment by tuning indicator;

2.3.2 adjustment for maximum audio output (see § 2.2.2);

2.3.3 adjustment for minimum distortion, in this case the harmonic distortion being the appropriate factor;

2.3.4 adjustment for minimum noise in output.

In this case, the effect of signal level on the choice of a criterion will be different from that of the amplitude-modulation receiver, in that for weak signals §§ 2.3.1, 2.3.2 or 2.3.4 may be appropriate (§ 2.3.4 probably being the most critical), whilst with strong signals only § 2.3.3 will be relevant.

To supplement an existing indicator, or to give an indication when there is none, a d. c. voltmeter can be connected to the output circuit of the discriminator (see Doc. II/34, Geneva, 1962).

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* These I.E.C. documents are at present under revision; the draft proposals are available from the I.E.C Central Office, Geneva.

As an alternative to § 2.3.4, the receiver can be tuned for maximum suppression of amplitude modulation.

Reference: § 4.8 of I.E.C. Publication 91.

2.4 *Receivers for monochrome television (A5C and A3) 405-line, positive modulation*

The criteria in this case are:

2.4.1 maximum sound rejection in the vision channel;

2.4.2 maximum audio-frequency output;

2.4.3 optimum picture quality, e. g. sharpest edge response with just tolerable overshoots.

Not only are these criteria of variable significance due to individual receiver design characteristics, but in a particular receiver it may not be possible to satisfy all tuning criteria at a single setting due to alignment errors between sound rejection, sound intermediate-frequency and vision intermediate-frequency circuits. These differences can be functions of input signal level, as well as temperature.

2.5 *Receivers for monochrome television (A5C and F3) 525- and 625-line negative picture modulation*

The majority of receivers now work with the sound channel on the inter-carrier principle and are tuned so that either:

2.5.1 optimum picture quality is achieved, e. g. sharpest edge response with just tolerable overshoots and maximum sound rejection,

2.5.2 correct indication is given on the tuning indicator.

Setting according to § 2.5.1 may depend on whether the receiver is tuned to a monochrome or to a compatible colour transmission.

In investigating the characteristics of a receiver, maladjustment or drift of the inter-carrier parts of the circuit may need attention. This involves alteration of the sound/vision carrier difference of the test signal.

Reference: for §§ 2.4 and 2.5, see § 1.4.8 of I.E.C. Publication 107.

2.6 *Receivers for colour television*

Any of the criteria in §§ 2.4 and 2.5 above, as appropriate, may be involved, but an additional criterion, which may be more discriminating, is that of a minimum level of the sound carrier/colour sub-carrier beat.

3. Tuning criteria for communication receivers

3.1 *Radiotelegraph receivers for aural reception (A1 or A2)*

For the reception of A1 signals, a beating oscillator is necessary to produce an audible output and such an oscillator is frequently used for the reception of A2 signals. The effect of receiver frequency-instability is to alter the frequency of the beat note and, independently of the IF passband width, stability is necessary to limit the variation of the beat note. The criterion of tuning for such a receiver is thus frequency of the beat note. If an audio-frequency filter is employed, the beat note should coincide with the centre of the passband of this filter.

3.2 *Radiotelegraph receivers for automatic reception (A1, F1 or F6)*

The necessity of using the minimum passband to achieve the best performance in the presence of noise and other signals has led to the general provision of automatic frequency control. With automatic frequency control (a.f.c.) in use, the receiver is always correctly tuned, provided that the a.f.c. reference frequency is correctly set relative to the passband of the intermediate-frequency filter; if the a.f.c. is of the type that does not correct to zero error, the maximum residual error should be small compared with the width of the passband.

There is no criterion of tune, other than that the a.f.c. should be in operation, but a check should be made that the a.f.c. reference frequency remains correctly related to the passband in spite of changes of temperature, voltage, etc.

The a.f.c. is usually fitted with a frequency scale, so the resultant drift of the receiver oscillators can readily be observed.

For receivers without a.f.c., means are usually provided to indicate correct tuning.

It is necessary to check that the centres of the passbands of the filters coincide with the zero point of the a.f.c. or tuning indicator.

3.3 *Single-sideband and independent-sideband radiotelephony receivers*

3.3.1 *Transmissions with fully-suppressed carrier (A3J)*

The receiver is correctly tuned when the frequency of its audio-frequency output is the same as that of the signal modulating the transmitter (see Doc. III/69, Geneva, 1962).

3.3.2 *Transmissions with reduced carrier (A3A or A3B) or with full carrier (A3H)*

When a pilot carrier is transmitted, it is used for automatic frequency and gain control, and the receiver remains correctly tuned, provided that the a.f.c. reference frequency is correct, relative to the centre of the passband of the carrier-selecting filter and of the frequency of the local oscillator which may be provided for use in demodulation. These frequency relationships should be correct in spite of changes of temperature, voltage, etc., and checks should be made to see that they are so.

The a.f.c. is usually fitted with a frequency scale, so the resultant drift of the oscillators can be recorded.

3.4 *Double-sideband radiotelephone receivers (A3)*

The criteria for tuning a double-sideband radiotelephone receiver are the same as those for an amplitude-modulation sound broadcasting receiver.

3.5 *Frequency-modulation radiotelephone receivers (F3)* *

The criteria for tuning frequency-modulation radiotelephone receivers are the same as those for a frequency-modulation sound broadcasting receiver.

* The effect of tuning drift in receivers for VHF radiotelephony may be evaluated by the reduction of adjacent-channel selectivity.

REPORT 189 *

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

(Question 3/II)

(1959 - 1963)

Question 3/II relates to appropriate methods of measuring the phase/frequency or group-delay/frequency characteristics of receivers. It has been recognized that these characteristics are important in connection with the quality of reception in receivers for television programmes and for HF telegraphy.

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

1. For HF telegraph receivers

Doc. II/15 (Japan), Geneva, 1958: a method and a special apparatus for measuring the group-delay/frequency characteristics of intermediate-frequency amplifiers in radiotelegraph receivers are introduced. It is well known that the intermediate-frequency stages have a predominating effect, especially in receivers used for high-speed radiotelegraphy, operated with frequency shift keying. The apparatus is of the direct-reading type and uses special signal generators which have automatic frequency sweeping devices, thus the group-delay/frequency characteristics can be observed directly on a cathode-ray oscilloscope.

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

2. Receivers for frequency-modulation

Doc. II/27 (France), Geneva, 1962: this document describes a new method for measuring the distortion produced by crystal filters, used to obtain selection of the first intermediate-frequency in a superheterodyne receiver.

The method described consists in measuring the audio-frequency distortion produced by the crystal filtering equipment under consideration, coupled to a set comprising a wide-band amplifier, followed by a discriminator and an audio-frequency amplifier, the inherent distortion of that set having been determined during a preliminary measurement.

To reach results permitting of comparisons with this method, the following measurement parameters should be standardized: frequency excursion, modulation frequency and the permissible frequency displacement of the test signal from the centre of the filter passband.

3. Receivers for radio-relay systems using frequency-modulation

Doc. II/33 (Italy), Geneva, 1962: this document describes a highly accurate method for measuring group-delay by determining the phase/frequency characteristics by a dynamic method.

* This Report, which replaces Report 104, was adopted unanimously.

With this method, the test signal, the frequency of which has to be varied throughout the bandwidth of the device under test, undergoes frequency conversion and is reduced to a fixed frequency applied to the discriminator. The heterodyning oscillator is frequency-controlled by the d. c. output of the discriminator, so that the fixed frequency coincides with the centre of the discriminator output/frequency characteristic.

This method offers many advantages over conventional methods [1].

4. Television receivers

4.1 Doc. 257 (Netherlands), Warsaw 1956: a direct reading method of measuring group-delay/frequency characteristics is reported. In the apparatus described, by employing a special phase-detection valve as a phase meter, the characteristics can be observed on the screen of a cathode-ray oscilloscope. By using this apparatus in combination with a signal generator which has an automatic frequency sweeping device, the group-delay/frequency characteristics of intermediate-frequency amplifiers of television receivers can be measured with an accuracy of 1 manosecond.

4.2 Doc. 488 (Federal Republic of Germany), Warsaw 1956: three methods for the measurement are described in this document. There is a slight difference between the three methods, but the principle is the same. The measurements are made by using two signal generators of an ordinary type. Thus, the phase/frequency characteristics can be measured without providing any special signal generator. The phase-delay is read on a phase indicator.

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REPORT 190-1 *

SUPPRESSION OF AMPLITUDE-MODULATION (CAUSED BY MULTIPATH PROPAGATION) IN FM RECEIVERS

(Question 9/II)

(1959 – 1963 – 1966)

1. Contributions relating to Question 9/II have been received in Docs. II/8 (Italy) and II/22 (United Kingdom), Geneva, 1958; Doc. 212 (P. R. of Poland), Los Angeles, 1959; in Docs. II/19 (P. R. of Poland), II/22 (Japan) and II/28 (United Kingdom), Geneva, 1962; and in Docs. II/6 (P. R. of Poland), II/13 (U.S.S.R.) and II/73 (P. R. of Poland), 1963–1966.

* This Report was adopted unanimously.

2. Method of measurement

2.1 These contributions use the direct-reading method for measuring amplitude-modulation suppression in frequency-modulation receivers, in preference to an oscilloscopic method.

Suitable direct-reading methods are described below.

2.2 The preferred direct-reading method uses simultaneous frequency-and amplitude-modulation.

Since, in practice, an average percentage of modulation of 30% is rarely exceeded for both frequency- and amplitude-modulation transmissions, this value of 30% is recommended for test purposes for both types of modulation.

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

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

2.2.2 The equipment used for measuring output should be preceded by a filter which sufficiently attenuates the fundamental and harmonics of the frequency-modulation as well as hum, and passes frequencies between 500 Hz and 3000 Hz with little attenuation.

A band-pass filter, with cut-off frequencies of 900 and 1100 Hz may also be used.

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

2.2.3 Initially, the signal is frequency-modulated at 1000 Hz and the receiver output adjusted to a convenient value; the simultaneous frequency- and amplitude-modulations described above are then applied and the output again measured with use of the filter; the ratio of the first measured value to the second is the amplitude-modulation suppression ratio.

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

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

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

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

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

3. Experimental results

3.1 It is reported, that under normal conditions of reception, the distortion due to multipath propagation can be substantially eliminated over a small range of tuning if the amplitude-modulation suppression ratio is at least 35 dB, measured by the method described in § 2.2, or at least 30 dB, measured by the method described in § 2.3, at each of the three carrier frequencies separated by 30 kHz.

3.2 Doc. II/22 (Japan), Geneva, 1962, gives the following data, measured at 470 MHz on transmissions over paths in city and hilly terrain where, due to multipath propagation, a maximum path difference of 150 µs and minimum amplitude ratio of 10 dB were observed between direct and indirect signal:

AM suppression ratio (dB)	*Distortion (%)*
> 40	< 3
35	4
30	7
25	9

If a professional high-fidelity frequency-modulation receiver with less than 2% distortion is required, these results indicate that an amplitude-modulation suppression ratio of more than 40 dB is required under severe multipath conditions.

3.3 Doc. II/28 (United Kingdom), Geneva 1962, gives results of measurements made using frequencies of 120 Hz and 2000 Hz showing the difference obtained between tuning for maximum output power at audio-frequency and tuning for maximum amplitude-modulation suppression. A check was made using frequencies of 100 Hz and 1000 Hz which gave the same results. For 45 comparisons, 29 cases were less than 3 dB different, 6 cases between 3 and 6 dB, 4 cases between 6 and 9 dB, 3 cases between 9 and 12 dB, 1 case between 12 and 15 dB and 2 cases between 15 and 18 dB.

3.4 According to Doc. II/6 (P. R. of Poland), 1963–1966:

- even if the limiter is very efficient, distortion due to multipath propagation may arise, because variations in the amplitude of the received signal may affect the local oscillation frequency and thus give rise to variations in the intermediate-frequency after mixing;
- special attention should be paid to the frequency stability of the local oscillator;
- comparative measurements on two transistorized frequency-modulation receivers (Doc. II/73 (P. R. of Poland), 1963–1966) confirm the previous statements. Further measurements will be made during the next period.

REPORT 191 *

TOLERABLE TUNING INSTABILITY OF RECEIVERS

(Question 4/II)

(1959–1963)

Two documents—Docs. II/2 (Federal Republic of Germany) and II/24 (United Kingdom)—concerning § 4 of Question 4/II were submitted to the Interim Meeting, Geneva, 1958. In particular, Doc. II/24 gives a Table listing the required stabilities for different kinds of receiver.

A systematic study of permissible instability seems desirable, on the basis of the documentation already available: Appendix 3 to the Radio Regulations, Geneva, 1959, on transmitter frequency

* This Report, which replaces Report 100, was adopted unanimously.

stabilization, Recommendation 332–1 on receiver selectivity and Recommendation 333 on receiver stability. More particularly, the values given in Recommendation 333 should be compared with the values actually required.

Attention is drawn to the fact that Appendix 3 deals with tolerances rather than stability. An example of the necessary stability is given by considering an A3B transmitter for HF (decametric waves): although the tolerance is $\pm 15 \times 10^{-6}$, a stability of about ± 10 Hz (i. e. $\pm 0{\cdot}5 \times 10^{-6}$ at 20 MHz) is necessary.

Values which are of interest could be tabulated in the form given in Table I, which gives an example based on proposed values, in particular those given in Table III of Doc. II/24 (United Kingdom), Geneva, 1958.

In Doc. II/2 (Federal Republic of Germany), it is stated that: " The maximum tolerable tuning instability depends essentially on the class of emission used, which in turn determines the necessary passband of the filters which follow the frequency change. It can be assumed, as a general rule that the central frequency of the signal in such filters cannot differ from its nominal frequency by more than 20% of the passband. This tolerance must be obtained either by manual or automatic tuning or by appropriate frequency correction. For receivers of single-sideband emissions, this will depend essentially on the narrow-band filter for the carrier. For receivers of F1 or F6 emissions (diplex systems, Recommendation 346), the frequency instability of the oscillators should not be more than 10% of the frequency deviation." (In the preceding sentence, the deviation is understood to mean half the total frequency shift from one significant condition of modulation to the other.)

TABLE I

Class of emission	Service	Range	Typical frequency (MHz)	Fractional frequency tolerance of the transmitter App. 3, R.R. (× 10⁻⁶) (2)	Bandwidth at 6 dB (Rec.332-1) (kHz) (2)	Man measured value of stability (Rec. 333)		Value proposed for the maximum permissible receiver drift from the typical frequency (1)		Time during which the stability in column 8 is required (hours)	Remarks
						(× 10⁻⁶) (2)	Times between which drift was measured (after switching on) (mins) (2)	Drift (kHz)	Relative drift (× 10⁻⁶)		
(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(8a)	(8b)	(9)	(10)
A3	Broadcasting	MF HF	1 20	10 15	5·5 8	170 80	10–120 10–120	1 1	1000 50	2 2	
F3	Broadcasting	VHF	100	20		220	10–120	15	150	2	
A5 (405 lines)	Broadcasting	Band I Band III	50 200	50 50		300 300	10–120 10–120	100 100	2000 500	2 2	
A3B	Fixed telephony	HF	20	15	6·5			0·01	0·5	10	Crystal(4) or a.f.c.
A3 (50kHz) between channels)	Mobile telephony	VHF	80 160	50 20	35 35	5 5	10–120 10–120	10 10	120 60	As long as the receiver is in use	Crystal
F3 (50kHz) between channels) $\Delta f = \pm 15$ kHz	Mobile telephony	VHF	160	20	35	5	10–120	5	30		
A1	Fixed telegraphy	LF HF	0·1 20	1000 50	0·2(3) 0·4			0·02 0·05	200 2·5	10 10	Crystal(4) or a.f.c.
F1	Fixed telegraphy	HF	20	50				0·01	0·5	10	Crystal(4) or a.f.c.
A1, A2	Maritime telegraphy	MF	0·5 0·5	200 200	3·2 3·2			0·3 1	600 2000	10 0·1	
		HF	20 20	200 200	1·4 1·4	4 70	60–120 1–10	0·3 1	15 50	10 0·1	

(1) This table deals only with the drift in time. For receivers in continuous use over long periods only, the value indicated for the maximum permissible drift should include the drift due to moderate changes in climate. Theoretically, the receiver should remain in tune (within the permitted tolerances), for the number of hours shown, computed from the instant when they are sufficiently warmed-up to furnish a suitable output signal. In practice, one may allow, for broadcast receivers, a warming-up period of about 5 minutes; for fixed service receivers, this period may be longer, for example a quarter of an hour.
(2) To be modified in accordance with further Recommendations as issued by Study Groups concerned.
(3) This figure is not given in Recommendation 332-1
(4) Crystal control of the receiver oscillator without a.f.c. can be employed, only if the accuracy and stability of the transmitter frequency are such, that the sum of the transmitter and receiver frequency errors and frequency variation due to propagation effects does not exceed the values given in column 8.

REPORT 192-1 *

TUNING STABILITY OF RECEIVERS

(Questions 4/II and 5/II)

(1959 – 1963 – 1966)

1. Stability of intermediate-frequency amplifiers with electro-mechanical filters, semi-conductor capacitors and ferromagnetic tuning

1.1

1.1.1 Electro-mechanical filters in intermediate-frequency amplifiers ensure high selectivity combined with small dimensions, which give rise to a rapid increase in their use in receivers.

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

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

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

1.3 According to the preliminary information received:

1.3.1 the coefficient of dependence of temperature on frequency, for crystal filters is better. than $2 \times 10^{-6}/°C$ (Doc. II/56 (Italy), 1963–1966);

1.3.2 the coefficient of dependence of temperature on frequency, for electro-mechanical filters, is of the order 2×10^{-6} to $5 \times 10^{-6}/°C$;

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

1.3.4 the temperature stability of filters with ferromagnetic tuning is at present worse than that of other types of filters with conventional coils.

1.4 Doc. II/14 (U.S.S.R.), Geneva, 1962, confirms that the instability of filters is made manifest by a variation, as a function of time, of the passband and its central frequency.

1.4.1 For intermediate-frequency filters with four circuits at 215 kHz, with variable passband and without crystals, used under normal conditions of temperature and humidity, measurements have shown that the drift of the central frequency amounts to 75 Hz in a year.

1.4.2 For crystal filters, having a passband of 0·5 kHz at a frequency of 150 kHz, the overall variation of the central frequency is approximately 40 Hz at the end of a year. The ageing factor, measured separately, is responsible for half that instability (20 Hz)

1.4.3 The lack of stability of filters with a passband of 3 kHz at the same frequency, when potassium tartrate filters are used, amounts to 200 Hz, not taking account of the. effects of ageing.

* This Report was adopted unanimously.

1.5 Because of insufficiency of information, further study is considered necessary and forms the subject of Questions 4/II and 5/II.

2. The frequency and phase stability of synthesized oscillations

In the course of the Interim Meeting, Geneva, 1965, two documents, Doc. II/11 (U.S.S.R.) and Doc. II/19 (F. R. of Germany), 1963–1966, concerning §§ 2 and 5 of Question 4/II, were presented.

Concerning § 2 of Question 4/II in Doc. II/19, some representative figures of tuning stability for entry in the Tables of Recommendation 333 are given, which can be attained with modern frequency synthesizers. Attention should be given to the fact that the presentation of new figures should state whether the interpolation oscillator is either continuously tunable or stabilized by a frequency spectrum derived from a standard oscillator.

Concerning § 5 of Question 4/II, both documents give a survey on the external and internal causes of spurious phase-modulation (e. g. fluctuations in power supply, influence of a.c. mains, noise, mechanical vibrations, etc.) and also an explanation of the physical phenomena which are of importance in this connection.

In Doc. II/11, the results of measurements on and some diagrams of a transistorized oscillator are presented, showing the relation between the spurious frequency-modulation and voltage fluctuations in the emitter and collector circuits.

In Doc. II/19, similar values are given for a frequency synthesizer containing an interpolation oscillator stabilized by a frequency spectrum. Finally in this document, a measurement procedure is mentioned for the determination of noise produced by spurious phase-modulation [1 - 5].

In Doc. II/60 (U.S.S.R.), 1963–1966, a typical reference oscillator is described including values of its stability.

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REPORT 193-1 *

SPURIOUS EMISSIONS FROM RECEIVERS

(Question 6/II)

(1959 – 1963 – 1966)

1. Broadcast and television receivers

1.1 In Doc. II/17 (C.I.S.P.R.), 1963–1966, the C.I.S.P.R. states in its Recommendation 24/1 (Stockholm 1964) the limits for radiation from sound and television receivers, and in its Recommendation 25/1 (Stockholm 1964) the limits for the mains interference ratio of long and medium-wave radio receivers.

1.2 Doc. 275 (Italy), Geneva, 1963, gives data (see Table I) on spurious radiations measured on some models 1960–1961 of television receivers equipped for UHF and VHF reception, according to the I.E.C. 3-meter method (Publication 106).

TABLE I

Channel	Radiated frequency (MHz)	Polarization	Local oscillator radiation (dB rel. 1 μV/m)			FCC limits		Number of receivers tested
						×10 (μV/m)	+20 dB (dB rel. 1 μV/m)	
			Max.	Mean	Min.			
A	99·5	H	72·0	54·5	42·9	500	54	11
		V	68·0	51·5	41·6			11
B	108	H	81·4	57·8	47·9	500	54	10
		V	74·9	52·4	40·8			10
C	128	H	81·9	58·6	42·9	500	54	9
		V	77·9	54·4	44·6			9
D	221	H	78·0	65·5	56·5	1500	64	9
		V	73·0	59·6	46·5			9
E	229	H	80·3	65·6	55·3	1500	64	10
		V	77·3	61·4	52·3			10
F	238	H	82·7	66·6	59·7	1500	64	9
		V	78·7	61·5	51·5			9
G	247	H	81·5	65·2	55·0	500	64	9
		V	77·5	61·5	54·0			9
H	256	H	83·2	67·8	56·3	1500	64	10
		V	82·2	65·7	57·1			10
A II	199	H	60·1	38·9	(1)	1500	64	11
		V	53·1	32·7	(1)	1500	64	11
B II	216	H	55·4	41·3	(1)	1500	64	11
		V	51·4	27·7	(1)			11

(1) Not given, too low to be measured, due to noise.

* This Report was adopted unanimcusly.

Channel	Radiated frequency (MHz)	Polarization	Local oscillator radiation (dB rel. 1μV/m)			FCC limits		Number of receivers tested
						× 10 (μV/m)	+ 20 dB (dB rel. 1μV/m)	
			Max.	Mean.	Min.			
F II	476	H	77·2	64·3	53·6	5000(²)	74	9
		V	76·2	61·4	48·6			9
G II	494	H	83·2	65·6	54·2	5000(²)	74	11
		V	76·2	64·3	55·2			11
H II	512	H	77·0	66·7	59·4	5000(²)	74	12
		V	74·7	65·6	56·5			12
C IV	512	H	56·5	51·9	45·5	5000(²)	74	12
		V	57·5	49·3	39·1			12
A V	497·5	H	56·7	48·1	34·0	5000(²)	74	11
		V	57·1	46·5	29·5			11
B V	540	H	58·0	49·0	34·0	5000(²)	74	12
		V	54·0	46·0	26·0			12
21	510	H	63·5	52·1	(¹)	5000(²)	74	12
		V	62·5	50·7	(¹)			12
33	610	H	72·0	52·2	(¹)	5000(²)	74	7
		V	69·5	48·8	(¹)			7

(¹) Not given, too low to be measured, due to noise.
(²) Is temporarily relaxed to 10 000 μV/m.

To assist comparison with the data in Table II, which was measured at a different distance a column, for information only, is given showing the FCC radiation limits multiplied by 10 (+20 dB). This corresponds approximately to the ratio of the distances. The I.E.C. is at present considering this relationship on a statistical basis.

TABLE II

Receiver	Oscillator radiation (μV/m) (for the signal frequency channels given below)			Power line conducted voltage (μV) (¹)	
	Channel 2-6 (54-88 MHz)	Channel 7-13 (174-216 MHz)	Channel 14-83 (470-890 MHz)	450–1600 kHz	4500 kHz
A	15	375	407	50	6
B	48	150	646	96	40
C	48	66	299	65	100
D	127	129	1012	110	210
E	23	112	512	45	24
F	27	117	302	60	12
G	214	1330	251	65	100
H	80	43	543	75	45
I	17	127	142	75	55
J	63	70	485	35	45
FCC limits	50	150	500 (1000) (²)	100	100

(¹) Measured in accordance with IRE Standards.
(²) Is temporarily relaxed to 1000 μV/m.

1.3 Doc. II/31 (U.S.A.), Geneva, 1962, gives data (see Table II), on spurious emissions from some 1961 model television receivers equipped with UHF/VHF tuners and tested by the FCC.

2. Receivers other than broadcast and television receivers

2.1 In Doc. II/17 (C.I.S.P.R.), 1963–1966, the C.I.S.P.R. states that the I.E.C. is working on methods of measuring and expressing the spurious radiations of communication receivers.

In Doc. II/18 (F. R. of Germany), 1963–1966, methods are described for measuring the oscillator output power at the antenna terminals of a well-screened receiver, and for measuring the radiation from a receiver with an incorporated antenna.

2.2 *High grade HF (band 7) communication receivers*

Examination of Doc. II/7 (Italy), Geneva, 1958, indicates that methods established by the I.E.C. and, in general, by national authorities, for measuring radiation from sound and television broadcast receivers are not suitable for special types such as high grade HF communication receivers.

In most cases, radiation is reduced sufficiently so as not to produce perceptible interference, even when a large number of such sets is in operation in close proximity to each other.

2.3 *Mobile service*

Doc. II/17 (United Kingdom), Geneva, 1962, gives national specifications used in the United Kingdom for spurious emissions from receivers as follows:

2.3.1 *MF and HF receivers for the maritime mobile service*

The following clauses contain the spurious emission specifications concerning the telegraph and telephone apparatus used for communication purposes and also the direction-finding and automatic alarm equipment.

" The receiver shall not, in normal service, produce a field exceeding 0·1 μV/m at a distance of one nautical mile. This will normally be regarded as satisfied if the following requirements are met:

(a) the receiver shall be placed centrally in a screened earth enclosure of dimensions at least six feet cube. The earth terminal of the receiver shall be connected to the inside of the screen;

(b) the antenna terminal shall be connected through an unscreened four-turn rectangular search coil (of dimensions one foot square), and an unscreened lead to a resistive measuring instrument mounted outside the enclosure, having its other terminal earthed;

(c) the receiver shall be energized;

(d) the power measured by the measuring instrument shall not exceed 4×10^{-10} W no matter what the resistance of the measuring instrument or the adjustment of the receiver. At the discretion of the testing officer, the search coil may be moved during the test in any way, provided that it does not approach within six inches of the receiver case; or it may be short circuited."

2.3.2 *VHF and UHF receivers for the maritime and land mobile services*

The maritime mobile services operate in the frequency range 156 to 174 MHz and the land mobile services operate in the ranges 71·5 to 88 MHz, 156 to 174 MHz and 450 to 470 MHz. The specifications apply to the coast and ship stations and to the base and mobile stations, and may be summarized as follows:

With the antenna terminals of the receiver closed with a resistance, equal to the source resistance from which the receiver is designed to work, the maximum power developed in the terminating resistance shall not exceed 0·02 μW at any frequency. The measurement is made in terms of the potential difference across the terminating resistance, using a test receiver calibrated by means of a signal generator. No method of measurement, or field-strength limitation, is given for the radiation from components and wiring.

REPORT 194 *

INTERFERENCE CAUSED TO FM RECEPTION BY AM AND FM VHF MOBILE STATIONS

(Question 3/II)

(1963)

Docs. 18 and 141 (Belgium), Geneva, 1963, concerning land mobile services, show that frequency-modulation reception can be interfered with by either amplitude-modulated or frequency-modulated emissions, whereas the conventional two-signal selectivity characteristic of the receiver under consideration does not show this possibility. A theoretical study ** confirms the experimental observations on this subject.

REPORT 327 *

DIVERSITY RECEPTION

(Question 7/II)

(1966)

1. General

Diversity reception methods are used for frequencies in the HF band (band 7) and above, to overcome fading, such as occurs in ionospheric propagation (particularly with multipath propagation), and variation of scattering properties or refraction such as occur in ionospheric scatter propagation or microwave transmissions.

The effects of these deficiencies in propagation depend on the type of emission and there are several methods of diversity reception that can be used to reduce them [1-5].

For the purpose of this Report, *diversity* characterizes those methods of transmission that make available at least two replicas of the received signal, equal except for at least partially uncorrelated fluctuations.

Contributions concerning Question 7/II have been provided in the following documents: II/2 and II/5 (United Kingdom), II/3 (U.S.A.), II/9, II/10 and II/64 (U.S.S.R.), II/23 (Federal Republic of Germany), II/26 and II/59 (Italy), 1963–1966.

2. Types of diversity reception

The following types of diversity reception are used: (Doc. II/3 (U.S.A.) and Doc. II/10 (U.S.S.R.), 1963–1966):

– spaced-antenna diversity, using two or more antennae (usually of the same type);

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* This Report was adopted unanimously.

** Revue HF (High Frequency), **5**, 8 (1962).

- polarization diversity using two antennae for mutually perpendicular polarization;
- wave arrival-angle diversity using two or more antennae with different directivity patterns;
- frequency diversity between the spectral components of a single or multi-channel emission or using more than one frequency allocation at the same time;
- time diversity, the signal being repeated with a suitable delay.

The type of diversity used depends on the type of emission, and more than one kind of diversity can be used in a single receiving installation.

2.1 *Spaced-antenna diversity*

Spaced-antenna diversity reception is most widely used in the HF and VHF bands.

With HF, according to [4, 6, 7], the relation between the correlation coefficient and the antenna spacing is satisfactorily given by the expression:

$$\rho = \exp - (\chi^2/2\,\chi_0^2)$$

where χ is the antenna spacing and χ_0 the spacing at which the correlation coefficient is reduced to 0·61.

It is found that with the antennae spaced in the direction of propagation, the correlation coefficient sometimes decreases more rapidly than when they are spaced perpendicular to this direction [8]. In the former case $\chi_0 \approx 10\lambda$ and in the latter $\chi_0 \approx 15\lambda$. Earlier studies of the influence of the direction in which the antennae are spaced in relation to the direction of propagation showed, that it has no significant effect on the effectiveness of diversity reception [9]. This conclusion has since been confirmed by other works [10, 11]. Consequently, the direction of the diversity has no appreciable significance; however, when the antennae are spaced less than 150 m apart, they should preferably be sited along the direction of propagation of the incident wave.

In line-of-sight radio-relay systems (2–6 GHz) only vertical space diversity is effective. A spacing of about 10 wavelengths is generally sufficient. On obstacle gain paths sometimes two vertically spaced transmitting antennae and two vertically spaced receiving antennae are used. For the reduction of prolonged fadeouts, very large vertical spacing of the antennae may be useful. For complete design considerations see [32].

In systems using tropospheric scatter, the correlation coefficient decreases more rapidly with an increase in the distance between the antennae, when these are sited along a line perpendicular to the direction of propagation than when they are sited along the direction of propagation; χ_0 is then equal to 12λ and 26λ respectively [12].

In these systems vertical diversity is to be preferred, as the horizontal diversity distance shows marked diurnal variations. Grosskopf has given the diversity distance as a function of the operational frequency and the half power width of the received beam in the direction of the antenna [9] [10]. In communication systems using ionospheric scatter, the correlation coefficient of 0·61 is attained with a spacing of 30λ along the path or $2{\cdot}5\lambda$ across the path [13].

See Report 266–1, § 6.

2.2 *Polarization diversity*

It would appear that polarization diversity could be used in all cases of ionospheric propagation. This applies both to earth and space communications.

Measurements on HF links [4, 14] have shown that signals received on closely sited dipoles perpendicular to each other, show fairly independent fading. As a rule, the correlation coefficient lies between 0·09 and 0·5, which indicates that completely effective systems of diversity reception are feasible.

Tests carried out in the U.S.S.R. show that polarization diversity gives results comparable with those obtained with space diversity with a distance of 400 m between antennae (Doc. II/64 (U.S.S.R.), 1963–1966).

However, on links using scatter propagation and on line-of-sight microwave links, the polarization of the signal remains unchanged and signals transmitted with vertical or horizontal polarization fade almost synchronously [15, 16].

2.3 *Wave arrival-angle diversity*

Reception with wave arrival-angle diversity is at present used on scatter propagation links. Angle diversity may be obtained with a single parabolic reflector with a directivity diagram split into two lobes, by selecting the energy from the separate areas of the scatter volume. When the width of each lobe is small in comparison with the angular spacing between the receiver and the transmitter, the required diversity may be obtained with only a slight change in the wave arrival-angle, that is without the substantial loss in the strength of the incoming signal which may occur when the diversity angle is too great. The theoretical relation between the correlation coefficient and the size of the angle diversity along the azimuth [17] shows that the correlation coefficient 0·61 may be attained when the angle diversity is nine-tenths of the width of the main lobe. Experimental data obtained on a tropospheric-scatter link [18] are in good agreement with those calculated. A calculation of the relation between the correlation coefficient and the size of the angle diversity with varying lobe widths is given in [19]; it is noted that with a decrease in the lobe width the correlation coefficient also decreases.

It is also noted [16], that on ionospheric scatter links, investigation of the fine structure of the signal, with angle diversity, revealed a lack of correlation in the diversity channels.

Antenna systems whereby diversity in the vertical plane can be obtained, such as the MUSA [20] and the travelling wave antenna [7], may be cited as examples of the application of angle diversity in the HF range.

2.4 *Frequency diversity and time diversity*

These two forms of diversity are discussed in § 3.

3. Telegraphy reception in the HF band (band 7)

In addition to the use of spaced-antenna diversity or polarization diversity, various forms of frequency and time diversity are employed. In this connection, ways of assessing the improvement due to diversity are considered and the combination of the outputs of the receivers used in diversity is discussed.

3.1 *Frequency diversity*

F1 emissions can be used as a form of frequency diversity, because the information given by the presence of the frequency corresponding to one of the significant conditions of modulation is repeated by the simultaneous absence of the frequency corresponding to the other condition: reception in two filtered channels can be used to give an improvement over other methods of reception (Report 195).

Since fading on frequencies separated by more than a few hundred hertz is largely uncorrelated in the HF band, this is a case of frequency diversity.

For the best performance of a frequency-division multiplex system, the frequencies corresponding to the two significant conditions of modulation of each channel should not be adjacent, e. g. in a three-channel system of six frequencies f_1 and f_4, f_2 and f_5, and f_3 and f_6 could be associated.

The term frequency-diversity is also used to describe the use of two channels of a frequency-division multiplex system to carry the same information. Diversity obtained by utilizing more than one frequency allocation is deprecated.

3.2 *Time diversity*

The use of automatic repetition (ARQ system) in the event of failure is a form of time diversity, as it relies on conditions being different at the time of repetition. This system requires the use of a return link.

In the absence of such a return link, a time-diversity system (Doc. II/3 (U.S.A.), 1963–1966) [27] employing two transmission channels with a delay of about 2 s in the second transmission of the signal can be used. Time diversity is most useful in overcoming time-variant components of the distortion which rarely lasts more than 1 second.

3.3 *Assessing the merits of different kinds of diversity*

There are two methods of specifying diversity effectiveness:

3.3.1 *Diversity gain*, i. e. the reduction in transmitted power resulting from the use of the diversity method for equal element error-rate;

3.3.2 *Error-rate improvement factor*, i. e. the reduction in element error-rate resulting from the use of the diversity method for equal transmitted power.

It is suggested that both methods of specifying the effectiveness of diversity be used, and that the number of diversity channels and the level of non-diversity error-rate, at which the improvement is effected, be specified. Additional time or bandwidth required to effect the diversity improvement should be considered in rating the merits of diversity schemes.

For zero correlation and Rayleigh fading, both diversity gain and error-rate improvement factor can be read directly from Figs. 1 and 2 of Report 195. For $\rho = 0{\cdot}4$ one loses 2 dB in dual diversity gain, and for $\rho = 0{\cdot}7$: 3 dB.

4. Output signal combination

According to the classification proposed in [21, 22], there are four basic ways of combining the signals in diversity reception (Doc. II/10 (U.S.S.R.), 1963–1966):

4.1 *Antenna switching*

This system of diversity reception covers a number of methods known as non-optimum selection. The antenna switching circuit connects the spaced antennae to the receiver in a given order until the signal the monitored parameter of which exceeds the specified limit, is found. This signal is used until its monitored parameter falls below the threshold; the search for the signal is then resumed.

The effectiveness of this system is analysed in [22, 23, 24], where it is shown [23] that for a negative correlation coefficient (—1) between the signals in the diversity antennae, and with equal transmission coefficients in each diversity channel and a Rayleigh field-strength distribution, the non-optimum selection method is nearly as effective as the optimum auto-selection method. However, with a positive correlation coefficient, the effectiveness is greatly reduced [22, 24].

It would appear that diversity with non-optimum selection could be used for reception of A3 and F3 transmission and also in A1 and F1 telegraphy.

4.2 *Selective addition, sometimes known as diversity with optimum selection*

Unlike the system described in § 4.1, this system simultaneously investigates the signals from N channels and selects the best. To achieve this in multiple diversity reception, N antennae and N receivers are required [21, 22].

It should be noted that, in diversity reception with automatic selection (optimum and non-optimum), switching gives rise to additional noise and its use is thus limited. Optimum selection with this method may be effected either at intermediate-frequency or at audio-frequencies or d. c. There is less noise when the intermediate-frequency is used.

4.3 *Diversity with maximum-ratio addition (quadratic addition)*

Provided a number of conditions are fulfilled [21, 22], the maximum ratio between the signal energy and the specific noise power one can obtain by means of diversity, is equal to the sum of the separate ratios in the diversity channels.

The optimum addition circuit weights the inputs in proportion to the signal-to-noise ratios in the corresponding sub-channels of the diversity system. The optimum system presupposes pre-detector coherent addition. It is optimum because it leads to the lowest element error-rate. Non-coherent addition gives a higher error-rate, but does not require phasing of the signals added (see Report 195).

4.4 *Diversity with equal amplification*

In this system, all the channels have the same amplification and the addition is effected linearly. Pre-detector linear addition ensures a degree of effectiveness closely approaching that obtained with quadratic addition. Non-coherent post-detector linear addition is less effective.

All the combination systems used in practice are related to the four methods enumerated above, or to combinations thereof.

5. A3 reception in the HF band (band 7) (Doc. II/2 (United Kingdom), 1963-1966)

Although A3 signals are frequently received on single-sideband receivers and the conditions are such as described in § 6, double spaced-antenna and polarization diversity are used if double-sideband receivers are employed.

Combined automatic gain control is used, so that the gain of both receivers is controlled by the strongest signal, and the receivers are adjusted to have equal gain.

The outputs of the receivers can be either combined or selected. In combination the output due to the weaker signal and the noise due to the second receiver are present. Electronic switches can select the stronger of the two audio-frequency outputs if the difference is 2 dB or more, but the operation of such a switch is often audible.

6. A3A, A3B and A3J reception in the HF band (band 7)

6.1 Tests made with triple spaced-antenna diversity have shown that with high-quality speech and music, improvements to " slightly better " or " much better " are obtained, but with telephone speech, little improvement was observed (Doc. II/5 (United Kingdom), 1963-1966).

Three methods of using the audio-frequency outputs were employed:

- direct combination;
- combination with an audio-frequency delay of 1 and 2 ms for the second and third receivers;
- selection by an electronic switch.

The delay combination gave the best results; selection improved the signal-to-noise ratio, but the change of quality that often occurred when the switch operated was considered disturbing.

It is concluded that, as there is no distortion resulting from the selective fading of the carrier (as occurs with A3), little advantage can be expected to result from diversity reception.

6.2 Tests made with dual spaced-antenna diversity using triple segmented band splitting at audio-frequencies have shown that with telephone speech, improvements in reception were noted in quality, due to a reduction in selective fading effects and in frequency usage, which afforded at least one hour longer frequency utilization before transition was required, as compared to single receiver operation.

The tests were made in the Pacific area over long-haul circuits during the Mercury Project (Doc. III/11 (U.S.A.), 1963–1966).

7. F1 ionospheric-scatter reception in the VHF band (band 8) (Doc. II/9 (U.S.S.R.), 1963-1966)

At 38 MHz at 300 bauds with 11 kHz spacing between the frequencies corresponding to the two significant conditions of modulation, signals have been received using frequency-diversity between corresponding signals as well as spaced-antenna diversity. The effect of inequalities of gain in the two receivers were investigated, and of inequalities of gain in the channels corresponding to the two significant conditions of modulation. A 6 dB difference in receiver gain reduced the diversity gain by 3·4 dB for an error-rate of 1 in 10 000 or doubled the error-rate for a 20 dB signal-to-noise ratio. A 6 dB difference between the gains of the two channels reduced the diversity gain by 4·5 dB or increased the error-rate of 1 in 200 by a factor of 1·6. With both gain differences present at the same time, the error-rate was 10 times as great.

8. Telephony and television relay at 2 and 6 GHz (Docs. II/26 and II/59 (Italy), 1963-1966)

Spaced-antenna diversity was used at 6 GHz and frequency-diversity at 2 GHz.

At 6 GHz over sea [25], fading of 27 dB for 99·9% of the time was reduced to 10 dB for antennae with zero correlation and to 4 dB by using antennae giving a negative correlation.

At 2 GHz over land [26], fading is frequency-selective, arising from multipath effects, and tests with frequency separations of 80 MHz reduced fading from 40 to 26 dB.

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REPORT 328 *

CROSS-MODULATION IN TRANSISTORIZED FM RECEIVERS

(Question 3/II, § 5)

(1966)

In the People's Republic of Poland a study of cross-modulation in transistorized frequency-modulation receivers has been made. In receivers equipped with a self-excited frequency-changer, cross-modulation may appear indirectly, i. e. the interfering amplitude-modulation or frequency-modulation signal leaking into the frequency-changer may modulate the heterodyne frequency. In this case, the voltage of the wanted intermediate-frequency signal resulting from the frequency change is subject to a supplementary interfering frequency-modulation due to the unwanted signal; this is cross-modulation.

Mathematical analysis and measurements have confirmed the presence of this phenomenon [1].

The spurious frequency-modulation can be reduced by a careful choice of oscillator operating conditions and of the Q-factor of the mixer-oscillating circuit. Moreover, the use of a mixer with a separate oscillator of adequate frequency stability reduces this type of cross-modulation almost to zero.

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REPORT 329 *

REMOTE-CONTROLLED RECEIVING STATIONS

(Question 8/II)

(1966)

1. The increasing importance of remote control of unattended HF receiving stations has been recognized in Doc. II/74 (Italy), 1963–1966.

2. The main technical points considered in this document as regards the remote control of a receiving station are the following:

2.1 Functions of the receiving station that are controlled (e. g. choice of antennae, switching of antenna attenuator, settings of oscillator frequencies, intermediate-frequency gain control);

2.2 Remote control system (number of control circuits used for the chosen functions).

* This Report was adopted unanimously.

REPORT 330 *

STABILITY MEASUREMENT OF PORTABLE FM RECEIVERS

(Question 5/II)

(1966)

Some portable frequency-modulation transistorized broadcast receivers have been submitted to stability measurements by simultaneous testing with two different procedures (Doc. II/55 (Italy), *1963–1966*):

- local oscillator frequency variation,
- variation of the signal generator frequency to obtain maximum suppression of amplitude modulation at the receiver output.

It has been found that the first procedure is much more sensitive than the second and consequently it is preferable although it does not take account of the variation of the circuit constants except those of the local oscillator.

REPORT 331 *

VALUES FOR THE CHARACTERISTICS OF TYPICAL RECEIVERS FOR THE FIXED SERVICE

(Study Programme 11A/II)

(1966)

1. The Tables given below are in the form corresponding to Study Programme 11A/II, whereas data provided by International Working Party II/1 on the subject were given with reference to the Tables and Notes printed in Volume I of the Documents of the Xth Plenary Assembly. The values inserted in the Tables below have been based partly on the data from the Working Party and partly on national specifications, and should be regarded as tentative. Separate values have not been given for typical (measured) and minimum (specified) characteristics as these were very close or overlapping for this class of receiver.

* This Report was adopted unanimously.

2. Fixed service telegraph receivers 1605 to 30 000 kHz

For notes on the characteristics, see Study Programme 11A/II (revised), §§ 1.2 and 1.3.1

TABLE I

Speed 100 bauds

Characteristics				F1[1]	F6[2]
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB		0·6	1·5
	A2	Bandwidth (kHz) at 30 dB		0·9	2·0
	A3	Bandwidth (kHz) at 60 dB		1·2	2·5
	A4	Intermediate-frequency rejection ratio (dB)		80	80
	A5	Image, etc. rejection ratio (dB)		80	80
Two-signal selectivity	B2	Level of adjacent signal (dB (μV)) with wanted signal 20 dB (μV)		90	90
	B3	Level of adjacent signal (dB (μV)) with wanted signal 60 dB (μV)		100	100
Three-signal selectivity		Level of unwanted signals for stated level of wanted signal			
	C1	$F_n' + F_n'' = F_{if}$	20 dB (μV)	80	80
	C2		60 dB (μV)	90	90
	C3	$F_n' - F_n'' = F_{if}$	20 dB (μV)	80	80
	C4		60 dB (μV)	90	90
	C5	$F_n' + F_n'' = F_d$	20 dB (μV)	80	80
	C6		60 dB (μV)	90	90
	C8	$F_n' - F_n'' = F_d$	20 dB (μV)	80	80
	C9		60 dB (μV)	90	90
	C10	$2F_n' - F_n'' = F_d$	20 dB (μV)	60	60
	C11		60 dB (μV)	80	80
Sensitivity	D1	Noise factor (dB)		7	7
	D2	Sensitivity (dB (μV))		—13	—9
Miscellaneous	E1	Tuning stability (Hz)		5	5
	E2	Spurious emissions (dB) (μV)		20	20

(1) For a frequency shift of 400 Hz.
(2) For a 400 Hz spacing between frequencies.

TABLE II

Speed 200 bauds

Characteristics		F1[1] typ.
Single-signal selectivity	A1 at 6 dB bandwidth (kHz)	0·7
	A2 at 30 dB bandwidth (kHz)	1·5
	A3 at 60 dB bandwidth (kHz)	2·0

(1) Frequency shift – 400 Hz.

3. Fixed service telephone receivers 1605 to 30 000 kHz

For notes on the characteristics, see Study Programme 11A/II (revised), §§ 1.2 and 1.3.2

Values are given for A3B receivers only, as sufficient data were not available for other types.

TABLE III

Characteristics				A3B
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB		13
	A2	Bandwidth (kHz) at 30 dB		15
	A3	Bandwidth (kHz) at 60 dB		
	A4	Intermediate-frequency rejection ratio (dB)		80
	A5	Image, etc., rejection ratio (dB)		80
	A6	Variation of group-delay time (ms)		
Two-signal selectivity	B1	Level of unwanted signal for 3 dB blocking (dB (µV))		100
	B2	Level of adjacent signal with wanted signal level stated	20 dB (µV)	70
	B3		60 dB (µV)	100
Three-signal selectivity		Level of unwanted signals for stated level of wanted signal		
	C1	$F_n' + F_n'' = F_{if}$	20 dB (µV)	80
	C2		60 dB (µV)	90
	C3	$F_n' - F_n'' = F_{if}$	20 dB (µV)	80
	C4		60 dB (µV)	90
	C5	$F_n' + F_n'' = F_d$	20 dB (µV)	80
	C6		60 dB (µV)	90
	C8	$F_n' - F_n'' = F_d$	20 dB (µV)	80
	C9		60 dB (µV)	90
	C10	$2F_n' - F_n'' = F_d$	20 dB (µV)	60
	C11		60 dB (µV)	80
Sensitivity	D1	Noise factor (dB)		7
	D2	Sensitivity (dB (µV))		8
	D3	A.g.c.: output variation (dB)		5
Miscellaneous	E1	Tuning stability (Hz)		5
	E2	Spurious emissions (dB (µV))		20

REPORT 332 *

VALUES FOR THE CHARACTERISTICS OF TYPICAL RECEIVERS FOR THE MOBILE SERVICE

(Study Programme 11A/II)

(1966)

1. The Tables given below are in the corresponding to Study Programme 11A/II, form whereas data provided by International Working Party II/1 on the subject were given with reference to the Tables and Notes printed in Volume I of the Documents of the Xth Plenary Assembly. The values inserted in the Tables below have been based partly on the data from the Working Party and partly on national specifications, and should be regarded as tentative. Separate values have not been given for typical (measured) and minimum (specified) characteristics as these were very close or overlapping for this class of receiver.
As sufficient data were not available for the Working Party, only a few of the Tables could be filled in and also these Tables are not complete.

2. **Maritime mobile service – ships main receivers – band 14 - 535 kHz**

For the notes concerning these characteristics, see Study Programme 11A/II, § 1.4.1.

TABLE 1.4.1

Characteristics			A1 Aural	A2 Aural
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB	1	3
	A2	Bandwidth (kHz) at 30 dB	5	10
	A3	Bandwidth (kHz) at 60 dB	10	20
	A4	Intermediate-frequency rejection ratio (dB)	60	60
	A5	Rejection ratio for image and others (dB)	60	60
Three-signal selectivity	C12	$2F'_n - F''_n = F_d$ Level of unwanted signals (dB (μV)) with wanted signal at sensitivity level		
Sensitivity	D2	Sensitivity (dB (μV))	25	30
Mis-cellaneous	E3	Frequency-setting error (kHz)		

3. **Maritime mobile service – ships main receivers – band 1605 - 28 000 kHz**

For the notes concerning these characteristics, see Study Programme 11A/II, § 1.4.3.

* This Report was adopted unanimously.

TABLE 1.4.3

Characteristics			A1 Aural	A2 Aural	A3
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB	1	3	6
	A2	Bandwidth (kHz) at 30 dB	5	10	15
	A3	Bandwidth (kHz) at 60 dB	10	20	30
	A4	Intermediate-frequency rejection ratio (dB)	60	60	60
	A5	Rejection ratio for image and others (dB)	20	20	20
Two-signal selectivity	B1	Level of unwanted signal for 3 dB blocking (dB (μV)	—	—	—
	B4	Level of unwanted signal (dB (μV) with wanted signal level at sensitivity level	—	—	—
Three-signal selectivity	C7	$F'_n + F''_n = F_d$, level of unwanted signals (dB (μV) with unwanted signal at sensitivity level	—	—	—
Sensitivity	D2	Sensitivity (dB (μV)	20	30	30
	D3	Automatic gain control: output variation (dB)	—	—	—
Miscellaneous	E3	Frequency-setting error (kHz)	—	—	—

4. Maritime mobile service – telephony receivers – bands 1605 - 3600 kHz

For the notes concerning these characteristics, see Study Programme 11A/II, § 1.4.5.

TABLE 1.4.5

Characteristics			A3	A3J
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB	6	
	A2	Bandwidth (kHz) at 30 dB	15	
	A3	Bandwidth (kHz) at 60 dB	30	
	A4	Intermediate-frequency rejection ratio (dB)	40	
	A5	Rejection ratio for image and others (dB)	30	
Two-signal selectivity	B1	Level of unwanted signal for 3 dB blocking (dB (μV)	80(1)	
	B4	Level of adjacent unwanted signal	80(2)	
Three-signal selectivity	C7	$F'_n + F''_n = F_d$, level of unwanted signals (dB (μV) with wanted signal at sensitivity level		
Sensitivity	D2	Sensitivity (dB (μV) for output conditions specified	30	
	D3	Automatic gain control: output variation (dB)	10	
Miscellaneous	E3	Frequency setting-error (kHz)		

(1) Wanted signal level 40 dB (μV).
(2) Wanted signal level 60 dB (μV).

5. Maritime mobile service – ships main receivers – bands 156-174 MHz

For the notes concerning these characteristics, see Study Programme 11A/II, § 1.4.7.

TABLE 1.4.7

Characteristics		A3	F3
Single-signal selectivity	A1 Bandwidth (kHz) at 6 dB		30
	A4 Intermediate-frequency rejection ratio (dB) A5 Rejection ratio for image and others (dB)		80
Two-signal selectivity	B4 Level of unwanted signal (dB (μV) with wanted signal level at sensitivity level		60
Three-signal selectivity	C12 $2F'_n - F''_n = F_d$ Level of unwanted signal (dB (μV)) with wanted signal at sensitivity level		
Sensitivity	D2 Sensitivity dB (μV) for output conditions specified		0
	D3 Automatic gain control: output variation (dB)		
Miscellaneous	E1 Tuning stability; reduction of two signal selectivity dB (μV)		
	E2 Spurious emissions, dB (μV)		

6. Land mobile service – Frequencies above 25 MHz

For the notes concerning these characteristics, see Study Programme 11A/II, § 1.4.9.

TABLE 1.4.9

		Frequency range, modulation, Channel spacing (kHz)	25–50 MHz F3 (± 5 kHz deviation) 20		132–174 MHz F3 (± 5 kHz deviation) 30		406–470 MHz F3 (± 15 kHz deviation) 50	
			Typ.	Min.(1)	Typ.	Min.(1)	Typ.	Min.(1)
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB	14		14		38	
	A4	Intermediate-frequency rejection ratio (dB)	—100	—85	—100	—85	—100	—80
	A5	Image rejection ratio (dB)	—100	—85	—100	—85	—100	—80
		Other spurious responses (dB)	—100	—85	—95	—85	—90	—80
Two-signal selectivity	B4	Adjacent-signal selectivity: level of unwanted signal with wanted signal at sensitivity level	80	70	80	70	70	70
Three-signal selectivity	C12	Intermodulation: $2F'_n - F''_n - F_a$	65	50	65	50	65	50
Sensitivity	D2	Sensitivity dB (μV) at 75 Ω (open circuit)	—4	0	—1	3·5	3	8
Miscellaneous	E1	Tuning stability (degradation of adjacent-signal selectivity (dB))	6	12	6	12	10	12

(1) The minimum values given are those specified by Standard RS-204, Electronic Industries Association, 1 January, 1958.

REPORT 333 *

VALUES FOR THE CHARACTERISTICS OF TYPICAL RECEIVERS FOR SOUND AND MONOCHROME TELEVISION BROADCASTING

(Study Programme 11A/II)

(1966)

1. Introduction

The Tables given below present the available values for the characteristics of typical sound and monochrome television broadcast receivers in the manner proposed in §§ 2, 3 and 4 of Study Programme 11A/II, which gives further details in notes concerning the methods of measurement, etc. The values are based on information provided by a limited number of Administrations, in some cases through the Working Party II/1 (see Doc. II/16, 1963–1966) and should be regarded as preliminary information only.

* This Report was adopted unanimously.

2. Sound broadcast receivers

TABLE I

Note. – Typical values as prescribed in Study Programme 11A/II, § 3, are given unless otherwise stated. They apply to ordinary home receivers.

Characteristic				A3 Band 525–1605 kHz			F3 Deviation $\pm$ 50 kHz	F3 Deviation $\pm$ 75 kHz	F3 Deviation $\pm$ 75 kHz
				(1)	(2)	(3)	(2)	(1)	(3)
Selectivity	Single-signal	A1	Passband at 6 dB points (kHz)		6(4)	6			
		A2	Attenuation, dB at $\pm$ 1 d	35					
		A3	Attenuation, dB at $\pm$ 2 d						
		A4	Attenuation, dB at $\pm$ 4 d						
		A5	Attenuation, dB at $\pm$ 8 d						
		A6	Image rejection ratio (dB)	34		40		30	54
		A7	Intermediate-frequency rejection ratio (dB)			46			54
		A8	Rejection of other spurious responses (dB)			40			60
	Two-signal	A9	Level of unwanted signal at $\pm$ 1 d (dB (μV))						
		A10	Level of unwanted signal at $\pm$ 2 d (dB (μV))					>60	W—8(5)
		A11	Level of unwanted signal at $\pm$ 3 d (dB (μV))						
		A12	Level of unwanted signal at $\pm$ 4 d (dB (μV))						W+15(5)
Sensitivity		B1	Sensitivity (dB (μV))		31(6)		—101(9)	—100	
		B2	Automatic gain control characteristic (dB)		57(7)				
Stability		C1	Frequency drift during heating-up (kHz)			1	27	150	40
		C2	Frequency shift due to $\pm$ 10% change in supply voltage (kHz)					60	
Miscellaneous		D	Mains interference ratio	38(8)	38(8)	38(8)			
Approximate number of receivers				14	80	>9	80	14	>9

(1) Contribution from Italy in Doc. II/16, 1963–1966.
(2) Contribution from U.S.S.R. in Doc. II/65, 1963–1966.
(3) Contribution from U.S.A. in Doc. II/68, 1963–1966.
(4) Values of 5·3 and 10·8 for receiver with switched selectivity.
(5) For signal-to-interference ratio of 30 dB and a wanted-signal level W approximately 60 dB (μV).
(6) dB (μV) referred to input; for a signal-to-noise ratio of 20 dB.
(7) dB (μV/m) for receivers with a built-in antenna; gain-limited, 50 mW output.
(8) This is the minimum value corresponding to C.I.S.P.R. Recommendation 25/1 (Stockholm 1964).
(9) For a signal-to-noise ratio of 26 dB.

3. Monochrome television receivers

For notes on the characteristics see Study Programme 11A/II, § 2.2.

TABLE II

		Band	I and III					IV and V	
	A1	System	B (1)	B (2)	B (3)	M (4)	D (5)	M (4)	G (3)
Selectivity – Attenuation (dB) at	B1	— 3·5 MHz							
	B2	— 2·5 MHz							
	B3	— 2 MHz	—	—	29	—	41	—	
	B4	— 1·5 MHz	36	34	10	50	39	50	
	B5	— 1·25 MHz	23	30	8	30	—	30	
	B6	— 1 MHz	14	10	6	21	—	21	
	B7	— 0·5 MHz	—	—	—	8	—	8	
	B8	0 MHz	0	0	0	0	0	0	
	B9	+ 1 MHz	—5	—5	—2	—5	—	—5	
	B10	+ 2 MHz	—5	—6	—2	—4	—	—4	
	B11	+ 2·5 MHz	—	—	—	—3	—	—3	
	B12	+ 3 MHz	—6	—6	—2	—2	—	—2	
	B13	+ 3·5 MHz	—6	—6	—1	0	—	0	
	B14	+ 4 MHz	—5	—5	1	9	—	9	
	B15	+ 4·5 MHz	—2	0	6	20	—	20	
	B16	+ 4·75 MHz	—	—	—	20	—	20	
	B17	+ 5 MHz	8	10	14	20	—	20	
	B18	+ 5·5 MHz	20	18	24	27	—	27	
	B19	+ 6 MHz	—	—	—	34	—	34	
	B20	+ 6·5 MHz	27	30	—	40	—	40	
	B21	+ 7 MHz	46	40	—	44	—	44	
	B22	+ 8 MHz	—	—	—	—	38	—	
	B23	+ 9 MHz	—	—	50(6)	—	—	—	
	B24	+ 11·15 MHz	—	60	—	—	—	—	
	B25	Image rejection ratio (dB)	50	50	—	60	—	40	
	B26	Intermediate-frequency rejection ratio (dB)	27	40	40(7)	90	>50	70	
	B27	Rejection ratio for other spurious responses (dB)	26	—	—	70	51	60	
Sensitivity	C1	Noise factor (dB)	—	4	—	7	—	12(8)	
	C2	Sensitivity (dB (mW))	—62	—	—72	—	—72	—	
	C3	A.g.c. characteristic (dB)	1·4	1·0	—	—	2·0	—	
	C4	Maximum usable input signal level (dB (mW))	>—4	—	—	—	—	—	
Stability	D1	Frequency drift during heating-up period (kHz)	164	—	—	150	—	500	630
	D2	Frequency change for a supply voltage variation of ± 10% (kHz)	5	—	—	100	—	200	35
Distortion	E1	Modulation-frequency response (dB)	25	—	—	—	—	—	
	E2	Unit step response: rise-time (ns)	208	250	200(7)	180	—	180	
	E3	Unit step response: overshoot (%)	17	10	10(7)	10	—	10	
	E4	Frame frequency square-wave response (%)	13	—	20(7)	5	—	5	
	E5	Group delay (total spread) (ns)	—	175	—	200	—	200	
Miscellaneous	F1	V.s.w.r.	—	—	—	2·5	—	2·5	
	F2	Balance ratio (dB)	21	—	—	20	—	20	
	F3	Black-level shift (%)	—	—	—	—(9)	—	—(9)	
Sound channel	G1	6 dB passband (kHz)	—	—	—	—	—		
	G2	Sensitivity (dB (mW))	—	—	—	—96	—77		
Approximate number of receivers					12	10		10	12

(1) Contribution from Sweden in Doc. II/A, 1963–1966.
(2) Contribution from New Zealand in Doc. II/B, 1963–1966.
(3) Contribution from Italy in Doc. II/16, 1963–1966.
(4) Contribution from U.S.A. in Doc. II/68, 1963–1966.
(5) Contribution from U.S.S.R. in Doc. II/65, 1963–1966.
(6) This measurement for 9 MHz corresponds to an average spacing of the vision carrier of the nearest channel, as it occurs in Italy.
(7) Minimum values considered good practice in Italy.
(8) A minimum-performance value of 18 dB is required by FCC regulations.
(9) Typical receivers have only partial or no d.c. r oratio .

4. Spurious emissions from sound broadcast and television receivers

Note. – Typical values as prescribed in Study Programme 11A/II, § 4, are given unless otherwis stated.

TABLE III

				Frequency of spurious emissions	Monochrome television M (1)	Sound broadcasting A3	Sound broadcasting F3 (2)	Sound broadcasting F3 (1)
Frequencies below 30 MHz	Injected voltage in dB (μV) including television time-base harmonics, and emission of oscillator, intermediate-frequency and other frequencies from television and amplitude-modulation receivers	Into the mains	Unbalanced	A1 150 – 500 kHz	35(3)			
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Unbalanced	A2 500 – 1605 kHz	32(3)			
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Unbalanced	A3 1605 kHz–4 MHz	30(3)			
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Unbalanced	A4 4 – 10 MHz	28(3)			
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Unbalanced	A5 10 – 30 MHz	—			
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Balanced	A6 150 – 500 kHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Balanced	A7 500 – 1605 kHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Balanced	A8 1605 kHz–4 MHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Balanced	A9 4 – 10 MHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the mains	Balanced	A10 10 – 30 MHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the antenna (AM receivers only)		A11 150 – 500 kHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the antenna (AM receivers only)		A12 500 – 1605 kHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the antenna (AM receivers only)		A13 1605 kHz–4 MHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the antenna (AM receivers only)		A14 4 – 10 MHz				
Frequencies below 30 MHz	Injected voltage in dB (μV) …	Into the antenna (AM receivers only)		A15 10 – 30 MHz				
Frequencies below 30 MHz	Radiation from television receiver time-base circuits	Electric in dB (μV/m)		B1 150 – 500 kHz				
Frequencies below 30 MHz	Radiation from television receiver time-base circuits	Electric in dB (μV/m)		B2 500 – 1605 kHz				
Frequencies below 30 MHz	Radiation from television receiver time-base circuits	Magnetic in dB (μV/m)		B3 150 – 500 kHz				
Frequencies below 30 MHz	Radiation from television receiver time-base circuits	Magnetic in dB (μV/m)		B4 500 – 1605 kHz				
Frequencies above 30 MHz	Radiation of local oscillator and its harmonics, intermediate-frequency and other spurious emissions (dB (μV/m)			C1 30 – 50 MHz	—			
Frequencies above 30 MHz	Radiation of local oscillator …			C2 50 – 100 MHz	—			
Frequencies above 30 MHz	Radiation of local oscillator …			C3 100 – 200 MHz	47(4)		32	50(4)
Frequencies above 30 MHz	Radiation of local oscillator …			C4 200 – 300 MHz	57(4)			
Frequencies above 30 MHz	Radiation of local oscillator …			C5 300 – 500 MHz	62(4)			
Frequencies above 30 MHz	Radiation of local oscillator …			C6 500 – 1000 MHz	68(4)			
Frequencies above 30 MHz	Approximate number of receivers				>21		80	7

(1) Contribution from U.S.A. in Doc. II/68, 1963–1966.
(2) Contribution from U.S.S.R. in Doc. II/65, 1963–1966.
(3) Measured with an artificial mains network having an impedance of 50 Ω rather than 150 Ω, and the value given is the larger of the two voltages from either line to ground.
(4) Measured by the IEEE method at 100 feet (30 m) distance, but the Table gives the result increased by 20 dB to be comparable with measurements at 3 m.

REPORT 334 *

CHARACTERISTICS OF RECEIVERS FOR RADIO-RELAY SYSTEMS

(Study Programme 11A/II)

(1966)

The typical and minimum values for the characteristics of receivers for radio-relay systems are a matter for Study Group II.

However, these characteristics depend essentially upon the form of the equipment required by these systems, and this is a matter for Study Group IX.

Consequently, Study Group II can prepare tables of typical and minimum values for the characteristics of this kind of equipment only when Study Group IX has established appropriate specifications.

Note. – Doc. II/16, 1963–1966 contains useful information submitted by Italy on these receivers (band 2 to 10 GHz) in the form of a table of characteristics. This information was included in the Conclusions of the Interim Meeting of Study Group II, Geneva, 1965, pages 57, 58.

* This Report was adopted unanimously.

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STUDY GROUP II

(Receivers)

Terms of reference:

The selection and study of the more important characteristics of the various types of receiver. Measurement of these characteristics of receivers and tabulation of typical values for the different classes of emission and the different services. Investigations of improvements that might be made to receivers to solve problems encountered in radiocommunication.

Chairman: Mr. Y. PLACE (France)

Vice-Chairman: Professor N. I. CHISTIAKOV (U.S.S.R.)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP II

1. Introduction

1.1 The C.C.I.R. Study Groups can be divided into two classes, according to the kind of work they do:

- Study Groups concerned above all with a particular service, studying the technical means whereby they might be more efficiently operated: Study Groups III, IV, VII, VIII, IX, X, XII, and XIII;
- Study Groups concerned with definite technical characteristics of each link in a radio circuit: Study Groups I, II, V, and VI.

This explains why Study Group II has to concern itself with a wide variety of devices, ranging from the pocket transistorized receiver to multiple-diversity multi-channel equipment of the utmost complexity. It follows that Study Group II has to concern itself with a wide variety of signals: Morse telegraphy, printed automatic telegraphy, stills, charts, photographs, data transmission, moving pictures, television, telephony, speech, music, etc. These signals in their turn may give rise to modulation of various kinds—amplitude-modulation, frequency or phase-modulation, and pulse-modulation.

1.2 Thus it is that Study Group II has been obliged to ascertain, first of all, what are the parameters whereby receiver characteristics may be defined. Three, it has decided, are fundamental: sensitivity, selectivity, and stability.

Thereafter, the Study Group had to decide how these should be measured, so that results can be compared.

The results, as and when sent in by Administrations have been arranged in tabular form, by category, and sometimes with statistical data appended (minimum, mean, maximum). The Study Group has then given thought to the means whereby such characteristics might be improved, and has given advice on the choice of circuits, components, etc.

All in all, at seven Plenary Assemblies and three Interim Meetings, Study Group II (set up in Stockholm in 1948) has little by little built up an edifice of recommendations, reports, questions, and study programmes. Its major texts are Recommendations 331, 332, and 333, which give the results of sensitivity, selectivity, and stability measurements.

1.3 The figures given in these three Recommendations for receiver characteristics are very scattered; it therefore seemed indispensable to lay down characteristic figures for each class of receiver, so that a typical receiver might be defined. The reason for this is as follows:

- All Administrations, and especially those which need special assistance, require some guidance in the choice of receivers;
- Accurate data have to be submitted to the International Frequency Registration Board (the I.F.R.B.) for the establishment of technical standards to facilitate the assessment of the probability of harmful interference.

To this end, between 1961 and 1963, Study Group II drew up Study Programme 185(II). Between 1963 and 1966, some replies to the points raised have been received, and, as we shall see in § 6, have been incorporated in further Reports.

The whole matter is evolving at great speed and will have to be followed closely in the years to come.

2. Sensitivity

2.1 This measures the ability of the receiver to pick up weak signals and to reproduce them with decent quality and adequate strength. Various things may happen:

- if amplification is low, sensitivity will be limited by the strength of the outgoing signal (and not by noise or distortion). It is called " amplification-limited ";
- if there is an amplification margin, as happens with most good modern receivers, the output level can always be made adequate, but weak signals will be mixed with noise, or distorted, so that the result is unpleasant to listen to, or full of errors. In these circumstances, we have to define a " maximum usable sensitivity, noise- or distortion-limited. "

Lastly, since no general agreement has yet proved possible on acceptable limits for the signal-to-noise ratio, distortion or error-rate, intermediate parameters have had to be introduced, such as " reference sensitivity " and " noise factor ", used for measurement purposes; from these actual performance can be deduced in each particular instance.

2.2 The problem as a whole is set forth in Recommendation 331-1, the way in which receivers are classified being explained in Annex I thereto. Annex II shows the relationship between actual sensitivity and the noise factor, and sets forth transition formulae. Annex III gives a few figures for noise factor. Lastly, numerous figures are provided for sensitivity and noise factor in receivers of various kinds; see in this connection Annexes IV (radiotelegraphy, radiotelephony and broadcasting), V (automatic telegraphy and fixed services), VI (frequency-modulation broadcasting), and VII (television).

Report 183-1 studies sensitivity in the presence of quasi-impulsive noise, while Question 1/II sets forth the points still demanding investigation.

All these texts were reviewed between 1963 and 1966 and brought up to date at the XIth Plenary Assembly, Oslo, 1966.

3. Selectivity

This measures the ability of the receiver to select the useful signal and to reject other unwanted, signals. It depends on three things:

- the width of the passband;
- the slope of the response curve (measured by the single-signal method);
- and, in the event of powerful interference, the appearance of beats, intermodulation, and other disturbances due to the non-linearity of the first stages. These shortcomings can be shown up only by the multi-signal method.

In superheterodyne receivers, we must also study intermediate-frequency and second-channel interference.

A last point which deserves attention is that selectivity modifies the phase characteristics with frequency, and hence both the group delay and the form of the transients. This may produce appreciable distortion in telegraphy and television.

Recommendation 332–1 gives a broad outline of these problems, with the relevant definitions. Thereafter a number of tables set forth the results ascertained. Annex I deals with telegraph, telephone and broadcasting receivers; Annex II with television; Annex III with frequency-modulation. Some figures for group delay in telegraph receivers are assembled in Annex IV.

Certain non-linear effects of a higher order are described in Report 190–1.

Other particular points are discussed:

- multiple-signal methods of measurement (Report 186–1);
- choice of intermediate-frequency (Report 184);
- protection against keyed sources of interference (Report 187);
- protection of FM reception against interference from AM or FM mobile stations (Report 194);
- suppression of amplitude modulation due to multipath propagation occurring in FM receivers (Report 185–1);
- crosstalk in FM transistorized receivers (Report 328).

An appeal is made to C.I.S.P.R., for help in the study of quasi-impulsive interference (Recommendation 334).

Studies to be continued are indicated in Questions 2/II, 3/II, 9/II and Study Programme 10A/II.

Report 328 is new. Recommendation 332–1, Question 3/II and Reports 185–1, 186–1, and 190–1 were brought up to date at the XIth Plenary Assembly, Oslo, 1966.

4. Stability

4.1 The stability of a receiver is its ability to maintain its performance with time, despite changes in temperature, in power supply voltage, and so on.

In superheterodyne receivers, the main cause of instability is drift in the first frequency-change local oscillator, leading to a loss of sensitivity and distortion of the wanted signal. But this drift can be corrected by adjusting the tuning or by an automatic tuning device.

Instability in switching equipment, selective filters, and so on, may be a source of disturbances harder to correct.

4.2 Recommendation 333 considers this matter in a general way. The Annex thereto gives some typical figures for stability, assembled in various countries on various receivers. Other figures are given in Report 191.

Report 188–1 discusses tuning criteria, while Report 192–1 draws attention to the stability of electromagnetic filters, semi-conductor capacitances and ferromagnetic tuning circuits.

Report 330 discusses the pros and cons of two ways of measuring portable FM receiver stability.

Questions 4/II and 5/II list the investigations felt still to be necessary in measurement of instability and its acceptable limits.

Report 330 is new. Reports 188–1 and 192–1 were brought up to date at the XIth Plenary Assembly, Oslo, 1966.

5. Diversity reception

5.1 The quality of very long-distance HF and radio-relay system communications (conventional or scatter) can often be improved by the use of diversity reception. There are many methods of diversity reception which have had to be classified and their pros and cons assessed. Studies in this connection are proceeding in conjunction with Study Groups III and IX.

5.3 With this aim, Study Group II between 1959 and 1963 drafted: Question 7/II and Report 327, which latter goes some way towards answering the Question. It was drafted between 1963 and 1966 and adopted in Oslo.

6. Typical receivers

6.1 As we have already said, Study Group II has tackled something new and important these last few years, namely, assessment of the minimum and mean (or median) characteristics of typical receivers for purposes of comparison. To this end, an international Working Party was set up between the IXth and Xth Plenary Assemblies. For the Xth Plenary Assembly, this Working Party drew up a Study Programme providing, for those persons who were taking part in the Study Group's activities, a basis on which they could make their own contribution towards the study of this matter. Between 1963 and 1966 this Working Party drew up four reports which went some distance towards answering the questions raised in the Study Programme.

The XIth Plenary Assembly decided that this international Working Party should pursue its studies.

6.2 The Study Programme, drawn up at the Xth Plenary Assembly, was brought up to date at the XIth and bears the number 11A/II.

The following new Reports were drawn up in response to this Study Programme:

- for fixed-service receivers: Report 331;
- for mobile-service receivers: Report 332;
- for sound broadcasting and black-and-white television receivers: Report 333;
- for radio-relay system receivers: Report 334.

Among the other tasks for which it is responsible, the international Working Party is called upon to harmonize the sensitivity measurement procedures given in Recommendation 331–1 and those recommended in Study Programme 11A/II.

7. Sundry problems

Recommendations 237 and 330, which were not amended at the XIth Plenary Assembly, make reference to the methods advocated by the International Electrotechnical Commission for testing broadcasting and television receivers.

The same holds good of spurious emissions produced by receivers of both types (Recommendation 239), although Report 193–1, brought up to date at the XIth Plenary Assembly, speaks of new results, supplied directly to the C.C.I.R. Question 6/II on this matter was not amended by the XIth Plenary Assembly.

Lastly, the XIth Plenary Assembly adopted a new Question 8/II and a new Report 329 in connection with remote-controlled HF receiver stations.

8. Questions and problems of particular concern to the new and developing countries

8.1 As we have said in § 1.3, one of the main purposes of the investigations called for in Study Programme 11A/II is to provide some guidance for Administrations, and especially those of the new and developing countries, for all kinds of receivers, so as to facilitate the drawing up of projects and the more accurate drafting of technical specifications.

The answers to Study Programme 11A/II accordingly represent an exceedingly valuable tool for the new and developing countries. Hence Study Group II should ensure that these answers are given as speedily and as completely as possible. To this end I would emphasize yet again, that Reports 331, 332 and 333 already go some way towards providing an answer for receivers in the fixed mobile, and broadcasting services.

8.2 The Recommendations and Reports drawn up during the first fifteen years of the life of Study Group II constitute a veritable mine of information. They include a very large number of definitions and measurement methods essential if receiver characteristics, given elsewhere, are to be properly understood and interpreted.

However, all this information is scattered over numerous different texts (Recommendations 331–1, 332–1, and 333, Reports 183–1, 186–1, and so on). Hence it would seem advisable to put some order into these texts and draft some general memorandum synthesizing all the information thus available. Such a task could suitably be undertaken by the C.C.I.R. Secretariat between now and the XIIth Plenary Assembly. The document thus produced would be of particular value for the new and developing countries.

QUESTION 1/II *

SENSITIVITY AND NOISE FACTOR

The C.C.I.R., (1948 – 1951 – 1953 – 1956 – 1959 – 1963 – 1966)

CONSIDERING

(a) that it is desirable to have available recent data on receiver sensitivity and noise factor;

(b) that there exist several different methods of measuring the sensitivity of receivers for F3 emissions for various services **, e. g.:

- to determine the input signal which gives a specific output signal-to-noise power ratio, as given in Table 1 of Recommendation 331–1;
- to determine the unmodulated input signal which causes a specified reduction in the output noise-power (quieting);
- to determine the input signal necessary for a specified ratio of (signal + noise + distortion) to (noise + distortion); (e. g. the method proposed by the Electronic Industries Association, U.S.A.);

(c) that, for receivers for amplitude-modulation it is possible:

- to determine the input signal which gives a specific output signal-to-noise power ratio, as given in Table I of Recommendation 331–1;
- to determine the input signal ncessary for a specified ratio of (signal + noise + distortion) to (noise + distortion);

(d) that, for radiotelegraphy receivers for automatic reception, it is desirable to have data on the maximum usable sensitivity limited by:

- signal distortion or mutilation,
- character-errors in the reproduced text;

(e) that the use of antenna amplifier-distributors in radio receiving systems may affect reception sensitivity;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are representative values of sensitivity and noise factor, for the various types of apparatus used for the reception of different classes of emission in the different services, and for receivers other than those for automatic reception of radiotelegraphy (see Recommendation 331–1, Annexes IV and VI);

2. for receivers for frequency-modulation, what methods of measurement should be used for receivers for various services, and what frequency-deviation and output criteria are appropriate;

3. for receivers for amplitude-modulation, what output criteria are appropriate;

4. for receivers for automatic reception of radiotelegraphy, what are the values of maximum usable sensitivity limited by:

* This Question replaces Question 228.
** For sound broadcasting receivers see Recommendation 237.

– signal distortion, mutilation or element error-rate *,
– character error-rate in the reproduced text *,

5. how is reception sensitivity affected if the signal does not reach the receiver input directly from the receiving antenna, but from an antenna amplifier-distributor?

QUESTION 2/II **

USABLE SENSITIVITY IN THE PRESENCE OF QUASI-IMPULSIVE INTERFERENCE

The C.C.I.R., (1953 – 1956 – 1959)

CONSIDERING

(a) that many types of interference—e. g. from atmospheric phenomena, ignition systems and electrical equipment—cannot be considered as either random noise or as simple isolated impulses, but may be regarded as " quasi-impulsive " and intermediate between those two cases;

(b) that, while the usable sensitivity of a receiver may be limited in some cases by the internal noise of the receiver (cf. noise-limited maximum usable sensitivity—Recommendation 331-1), in other cases, and in most services, it may be limited by external quasi-impulsive interference, and that it is desirable to have a standard method of measurement for this sensitivity;

(c) that methods are available for describing certain types of noise and for calculating their effects upon the receiver for the case of telegraphic reception (see Report 183–1);

(d) that it is possible to develop pulse generators representing the effects of some types of quasi-impulsive interference, for example, for facilitating theoretical as well as practical studies of the response of receivers to such interference;

(e) that representative values, for the response of receivers to quasi-impulsive interference, are necessary for system planning purposes, and that data on the values of quasi-impulsive interference, permissible in normal operation, are required;

UNANIMOUSLY DECIDES that the following question should be studied:

1. is it possible for Administrations to determine practically, and in a satisfactory manner, the characteristic values of the interference as they have been defined in Report 183–1, and to calculate the susceptibility of telegraphic receivers subjected to such interference;

2. is it possible to extend these methods to other types of receiver, such as those used for telephony and television;

3. is it satisfactory to substitute a pulse generator (e. g. generating pulses of identical shape at a controllable average rate and with a controllable amplitude distribution), at the input of the receiver, for a source of interference, and does this simulate, with good approximation, the effect of quasi-impulsive interference;

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* Using, for example:
– the Q9S code (C.C.I.T.T. Recommendation R.51, Vol. VII)
– the standard synchronized arrangement for Q9S-text (idem)
– a noise-keyed generator.

** Formerly Question 175(II).

4. what are the methods of measuring the most useful definitions of the response of receivers to quasi-impulsive interference, taking into account any non-linear effects that may occur in practice;

5. what is the amount of quasi-impulsive interference permissible in normal operation for a given signal level;

6. what are representative figures for the impulse-limited sensitivity of receivers?

Note 1. – The above question should again be brought to the attention of the U.R.S.I., and the C.I.S.P.R., by the Director, C.C.I.R., with a view to encouraging these organizations to expedite their work bearing on these studies, requesting these organizations to inform the C.C.I.R. of the results of this study.

Note 2. – It is considered that the information obtained as an answer to §§ 1, 2, 5, and 6, should be communicated to the C.I.S.P.R. as soon as possible.

QUESTION 3/II *

SELECTIVITY OF RECEIVERS

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

CONSIDERING

(a) that selectivity measurements so far produced have been limited primarily to receivers suitable for A1, A2 and A3 classes of emission, little information being available for other types of receiver (F1, F2, F3, F4, pulse-modulation, television, etc.);

(b) that such measurements, as are available, have chiefly been made by the single-signal method, not enough information being available on measurements made by the multiple-signal method;

(c) that, in determining the selectivity of the receiver, that is to say, its ability to separate the wanted signal from unwanted signals, there are cases where the determination of the usua- selectivity curve (amplitude/frequency characteristic) is insufficient and that other character istics should be taken into consideration;

(d) that multiple-signal methods, suitable for receivers for A1, A2, F1 and F3 signals, have not been fully considered;

(e) that there are numerous instances where this is true, particularly where the signal shape may be of importance (e.g. telegraphy, facsimile, pulse-modulation, television);

(f) that certain factors, such as the non-linearity of various stages of the receivers, amplitude-modulation suppression, the time constant of detectors, etc., play an important part in determining the multiple-signal selectivity of receivers;

(g) that cross-modulation and intermodulation, of the type $F_a = 2F'_n - F''_n$, can be calculated one from the other as far as the frequency-differences between F'_n, F''_n and F_a are small compared with the input (radio-frequency) bandwidth of the receiver, because both are effects of third-order distortion of the radio-frequency stages;

(h) that the non-linearity of the antenna amplifier-distributor from which several receivers are often fed may in practice affect overall receiving selectivity;

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* This Question replaces Question 229.

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are representative figures for the single-signal selectivity of types of receiver, for classes of emission other than A1, A2 and A3;

2. what are the representative figures for interference in frequency-division multiplex systems (especially radiotelegraphy), in neighbouring channels due to transients in any channel;

3. what methods are suitable for measuring and expressing the multiple-signal selectivity of receivers for A1, A2, F1 and F3 signals *;

4. what are representative figures for multiple-signal selectivity of various types of receiver, including those for classes of emission A1, A2, A3, F1 and F3;

5. what are the design features in receivers affecting the multiple-signal selectivity and how should their parameters be chosen to minimize interference from unwanted signals;

6. in what circumstances does cross-modulation adequately represent third-order non-linear effects; when is it necessary to assess the effects of combined interference of the type $(2F'_n - F''_n)$;

7. how is the receiving selectivity affected by the fact that the signal does not reach the receiver input directly from the receiving antenna, but after passing through a communal antenna amplifier-distributor?

Note. – Contributions to the study of this Question are contained in Docs. 31 (Japan) and 102, 105, 106, 108, 110 and 123 (U.S.S.R.), Los Angeles, 1959, and Doc. II/53 (U.S.S.R.), 1963–1966.

QUESTION 4/II **

TUNING STABILITY OF RECEIVERS

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

CONSIDERING

(a) that the values collected on tuning stability (see Recommendation 333) occasionally show that there are wide variations for receivers of the same type;

(b) that, in certain receivers, automatic frequency-control (a.f.c.) is provided to reduce the effect of instability of receiver oscillators and variation of the signal frequency due to propagation effects, as well as variations in the transmitting frequency;

(c) that, in certain receivers, e. g., those in which the frequency-change oscillators are crystal controlled or those which incorporate automatic frequency control, the stability of the filters may be a deciding factor in determining the overall stability;

* Doc. 109, Los Angeles, 1959, contains some opinions on this point.
** Formerly Question 230(II).

(d) that there is insufficient information on the permissible values of unwanted phase-modulation of conversion-frequency voltages in receivers with frequency synthesizers;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the maximum acceptable values of the tuning instability of receivers designed for various purposes, taking into account typical frequency-response curves for the receivers used;
2. what are the data on tuning instability under various operating conditions, more particularly as regards wide temperature variations and ordinary temperature, humidity and supply voltage variations;
3. what measurements are necessary to determine the performance of a.f.c. systems, in respect of accuracy of synchronization, capture range, speed of operation, etc. *;
4. what are representative values for the stability achieved, for instance, with crystal filters, magnetostriction filters, complex filters with electrically controlled characteristics, etc.;
5. what are the permissible values for the parameters of phase-modulation of conversion frequency voltages in receivers designed for different services, using frequency synthesizers?

Note. – Administrations are requested to present the results in the form laid down in the Annex to Recommendation 333.

QUESTION 5/II **

ASSESSMENT OF STABILITY OF A RECEIVER

The C.C.I.R., (1959 – 1963)

CONSIDERING

(a) that criteria and methods for assessing the stability of receivers used for the various services should be improved;

(b) that, because of the complexity of the effects which result from lack of sufficient stability, there must be consideration of several aspects (fidelity, signal-to-noise ratio, selectivity, etc.);

(c) that the frequency variation of the local oscillator is the main cause of instability, but not the only cause;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what criteria and methods for assessing the stability are preferred for each class of receiver, fixed or tunable, and for any type of service;
2. in particular, does a measurement of the degradation of two-signal selectivity constitute a useful criterion for certain types of receiver? ***

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* Some information is available in Doc. II/5 (Federal Republic of Germany), Geneva 1962.

** Formerly Question 231(II).

*** See § 5.1 of Annex III to Doc. 130 (Sweden), Geneva, 1963.

QUESTION 6/II *

SPURIOUS EMISSIONS FROM RECEIVERS EXCLUDING SOUND-BROADCAST AND TELEVISION

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

CONSIDERING

(a) that many receivers, excluding special types, such as high grade HF long-distance communication receivers (see Report 193–1), produce spurious radiation which may harmfully interfere with different services;

(b) that I.E.C. Publication 106 lays down methods of measurement only for emissions from sound-broadcast and television receivers;

(c) that the C.I.S.P.R. is, as a matter of priority, firstly establishing limits for the emissions from sound-broadcast and from television receivers which affect other similar receivers;

UNANIMOUSLY DECIDES that the following question should be studied:

1. to what extent is it necessary for the C.C.I.R. to establish methods of measurement and limits for undesired emissions from types of receiver, other than sound-broadcast and television;

2. are the methods established by the I.E.C. for measuring emissions from broadcast and television receivers also suitable for measuring the emissions from other classes of receiver; if not, what methods should be used;

3. what are typical values for fields in the different bands and, possibly, for different types of service, that should not be exceeded by these undesired emissions;

4. what are the best techniques to reduce these fields?

QUESTION 7/II **

DIVERSITY RECEPTION UNDER CONDITIONS OF MULTIPATH PROPAGATION

The C.C.I.R., (1962)

CONSIDERING

(a) that multipath propagation is one of the major factors causing distortion of received signals;

* Formerly Question 176(II).
** Formerly Question 225 (II).

(b) that, in many instances, methods of diversity reception substantially reduce the effect of multipath propagation and increase the reliability of radiocommunications;

(c) that numerous methods of diversity reception, such as space diversity, frequency diversity, polarization diversity, diversity of wave arrival-angle in the vertical plane, etc., and numerous systems for putting these methods into practice have been devised;

(d) that there exists no clear classification of the various diversity methods and systems, and no assessment of their respective merits, with the result that the choice and wide-scale use of the best systems is rendered difficult;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what classification of diversity reception methods could be proposed, with a view to including all those of practical interest for the various services, in the various bands, and for the various classes of emission;

2. what would be the best ways of assessing the effectiveness of diversity reception, under the conditions described in § 1;

3. how effective are the individual methods?

QUESTION 8/II

REMOTELY CONTROLLED HF RECEIVING STATIONS

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

CONSIDERING

(a) that HF receiving stations should be sited in locations practically free of man-made noise and therefore many Administrations are compelled to erect new receiving stations in areas well away from industrial centres and towns;

(b) that it is often difficult to recruit technical staff to operate the receiving stations in remote areas;

(c) that there exists a general trend in all the services to encourage automation and so to reduce the technical personnel required;

(d) that reduction of the interference level and introduction of automation could result in a better operation of the receiving stations and so could improve the quality and reliability of HF communications;

(e) that several Administrations are studying the problems involved in applying remote control to HF receiving stations and are encountering certain difficulties;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the problems raised by the remote control of HF receiving stations, according to the various services;

2. what are the special characteristics of an HF receiver designed to be installed in a remote-controlled station;

3. what are the required characteristics of the controlling system, taking into account reliability of control and economy of circuits and equipment?

QUESTION 9/II *

DISTORTION IN FREQUENCY-MODULATION RECEIVERS DUE TO MULTIPATH PROPAGATION

The C.C.I.R., (1956 – 1959 – 1966)

CONSIDERING

(a) that experience with VHF (metric) frequency-modulation broadcasting and other services has shown that secondary, delayed signals may be received in addition to the primary signal;

(b) that both the phase and the amplitude of the composite signal will thereby be affected;

(c) that not all receivers have directional antennae discriminating effectively against reception of the secondary, delayed signal;

(d) that efficient circuits (for example, limiters associated with ratio-detectors), in the receiver, will reduce the effect of amplitude variations, without impairing the suppression of impulsive interference, but in some receivers these circuits may be missing, be inadequate or require critical tuning;

(e) that consequently the subjective effect of residual amplitude-modulation of the composite signal may be much more serious than that associated only with phase distortion, particularly if the path difference between the primary and secondary signals is large, for example, 8 km or greater;

(f) that display method of measurements, as described in I.E.C. Publication 91 " Recommended methods of measurement on receivers for frequency-modulation broadcast transmissions ", are insufficiently sensitive for C.C.I.R. purposes;

UNANIMOUSLY DECIDES that the following question should be studied:

1. are the methods described, and the input signal levels recommended in Report 190-1, suitable for measuring amplitude-modulation suppression in FM-VHF receivers;

2. what values are obtained using the above methods;

3. what is the minimum amplitude-modulation suppression ratio necessary to eliminate, as far as is practicable, avoidable distortion of the received signal, for typical values of path-difference and amplitude-ratio between the direct and indirect signals;

4. what are the design characteristics of frequency-modulation receivers which affect amplitude-modulation suppression and distortion, during the reception of signals by multipath propagation and how should the relevant parameters of these receivers be chosen to reduce this distortion to the minimum?

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* This Question replaces Question 177.

STUDY PROGRAMME 10A/II *

PROTECTION AGAINST KEYED INTERFERING SIGNALS

The C.C.I.R., (1951 – 1953 – 1959)

CONSIDERING

(a) that the reduction of interference between adjacent channels is a very important problem, the solution of which should be sought with great care and by all possible means;

(b) that, for keyed telegraph transmissions, a partial solution has already been reached by considering separately:

- the transmitter, by reducing the extent and amplitude of the spectrum (Recommendation 328–1);
- the receiver, by increasing the selectivity in regular operation (reduction of bandwidth and increase of slope on each side of the passband) (Recommendation 332–1).

These measures are quite effective when applied simultaneously and have already led to important improvements, but do not fully solve the problem;

(c) that, in practice, telegraphic emissions involve, outside the band necessarily occupied, components of levels in excess of that indicated in Recommendation 328–1; while, even with the rounding of the keyed signals at present in use, the spectrum often still encroaches on the necessary band of an adjacent channel, thus preventing full advantage being realized from the high selectivity possible in receivers;

(d) that, on the other hand, the envelope of the components of the emitted spectrum and the selectivity curve of the receiver, obtained in normal or non-keyed operation, are not the only factors involved;

(e) that, for instance, Recommendation 328–1 indicates the limit-contour within which the amplitudes of the different components should be restricted; but that the amplitude and phase of each individual component can vary in accordance with the manner in which the restriction is achieved; the resulting distortion of the shape may also vary;

(f) that the selectivity curve of receivers is not perfectly rectangular, but there is some irregularity in the passband response and a limited slope on the sides of the passband, so that each component of the signal suffers some change in amplitude; furthermore, they suffer a phase change, usually of an indeterminate amount, which increases with increasing slope of the sides of the passband. In combining these components, the resultant output signal differs in shape from the input signal; this may result in amplitude distortion effects. Further distortion may be caused by non-linearity in other parts of the receiver;

(g) that it is difficult to calculate the distortion mentioned in §§ *(e)* and *(f)*, or the total distortion which results over the complete transmission system; in particular, if the total distortion is fixed, that is, if the quality of the transmission is predetermined, it may be that the division of distortion between receiver and transmitter could modify the interference produced in adjacent channels; in this case, the division should be chosen so as to produce minimum interference. The theoretical optimum division might, of course, have to be modified in the light of technical difficulties or economic factors (relative costs of filter circuits at transmitter and receiver, etc.), and of propagation effects;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the interference produced when the wanted and unwanted signals have such degrees of rounding as are implied in Recommendation 328–1;

* Formerly Study Programme 127(II). This Study Programme does not refer to any Question under study.

2. investigation of the receiver characteristics which will, for the wanted signal, add the least possible distortion to that produced by the rounding of the dot at the transmitter, but at the same time provide the greatest possible protection against adjacent keying signals; the investigation should include also the transient effects in the receiver, which are influenced, not only by the usual selectivity curve (amplitude/frequency characteristic), but also by the phase/frequency characteristic and by non-linearity;

3. investigation of the total permissible rounding of dots from the transmitter input to the output of the receiving apparatus on a system basis, to reduce interference to a minimum while retaining a maximum of intelligibility, with special attention to the best compromise on the fraction of the rounding to be assigned to the effects of the transmitter, of propagation and of the receiver respectively (see Note);

4. the investigation should be made with the wanted and the unwanted signals of A1, A2, F1 and F4 type in all possible combinations, and for various keying speeds and frequency shifts;

5. the extent of the interference when the lowest level of the wanted signal is such, that the distortion or mutilation resulting from noise is negligible; the level of the unwanted signal which is recorded should be that which produces the degree of distortion or error-rate used for measurements of sensitivity in Recommendation 331-1 (Annex II, § 5), and should be measured, using as parameters, the frequency-spacing and the strength of the wanted signal;

6. the extent of the interference when the wanted signal is A3 (telephony and sound broadcasting) and A3B (single-sideband telephony).

Note. – Study Programme 43, § 3, contained a programme of investigation into the division of the rounding of the signals between the transmitter and the receiver. Since this aspect of the question concerns the whole circuit, it was decided in Geneva, 1958, to confide it to the new mixed Working Group (I, II and III) established at that time.

In these conditions, Study Group II has ceased to discuss this point and is content to record the contributions in the following documents: 236 (Netherlands), London, 1953, 2 (Netherlands), 9 (Belgium), 319 (Japan) and 174 (France), Warsaw, 1956 and I/31 (United States of America), Geneva, 1958.

It notes also, that there is a connection between this subject, Report 178-1 and Study Programme 1A (III).

STUDY PROGRAMME 11A/II *

TYPICAL RECEIVERS

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

CONSIDERING

(a) that No. 636 of the Radio Regulations, Geneva, 1959, requires that the technical standards of the International Frequency Registration Board shall be based, *inter alia*, upon the Recommendations of the C.C.I.R.;

(b) that No. 668 of the Radio Regulations, Geneva, 1959, requires that, as far as is compatible with practical considerations, the choice of receiving equipment shall be based on the most recent technical progress, as indicated, *inter alia*, in the C.C.I.R. Recommendations;

* This Study Programme, which replaces Study Programme 185, does not refer to any Question under study.

(c) that Recommendation No. 6 of the Administrative Radio Conference, Geneva, 1959, invites the C.C.I.R. to continue the study of the characteristics of various types of apparatus used for the reception of different classes of emission in various services;

(d) that Part D, Section III, No. 8 of the Interim Report of the Panel of Experts, Geneva, 11–29 September, 1962, draws attention to the necessity for the C.C.I.R. to study minimum values of the characteristics of receivers;

(e) that it is necessary for all Administrations, particularly those who need special assistance, to have available a guide to help them in the choice of characteristics of various categories of receivers;

UNANIMOUSLY DECIDES that the following studies should be carried out:

to determine, for all categories of receiver *, the following two types of characteristic values:

1. Acceptable (recommended) minimum values

The minimum values are the limiting values that give an acceptable performance in the transmission system of which the receiver is part.

Some acceptable minimum characteristics of certain categories of receiver are the subject of national or international specifications.

When there are divergencies between the proposed acceptable minimum values, a mean value should be adopted.

2. Typical values (measured)

The typical values should, in principle, be the median of those values measured on receivers based on the most recent technical progress (the median value is that which is exceeded by 50% of the receivers). However, when the number of receivers measured is too small to establish median values, Administrations should have the possibility of indicating the value of the arithmetic mean.

When the receivers are mass-produced, as is the case with sound and television broadcasting receivers, the sampling process used should be such as to give a correct representation of the receivers considered.

Furthermore, Administrations should also give some additional information: the number of receivers tested, the date of manufacture, the date of test and references to the standards of test.

Note 1. – Administrations are requested to propose other categories of receiver and other characteristics that might supplement those already contained in the Annex to Study Programme 11A/II.

Note 2. – The tables drawn up in accordance with Study Programme 11A/II may eventually replace the existing tables annexed to Recommendations 331–1, 332–1 and 333, when they include a sufficient amount of information on the most recent technical characteristics of the various categories of receiver. This replacement may be effected progressively by categories of receiver.

ANNEX

General

The Annex to the Study Programme is in the form of tables.

This Annex is divided into 4 main parts, corresponding to the following sections:

* Administrations should give their attention first to receivers for fixed and mobile services, and sound and television broadcasting; subsequently, studies should be carried out on receivers for special services, e.g. for radio-location and radionavigation.

§ 1: fixed and mobile services;

§ 2: monochrome television;

§ 3: sound broadcasting;

§ 4: spurious radiation from sound and television broadcast receivers.

Each of the §§ 1, 2 and 3 begins with a list of characteristics. This is followed by general notes related to the lines of the list of characteristics. Then follow the Tables, accompanied by special notes.

Section 1 is also divided into two: fixed service and mobile services.

1. Fixed and mobile services

1.1 *List of characteristics*

Characteristics				
Single-signal selectivity	A1	Bandwidth (kHz) at 6 dB		
	A2	Bandwidth (kHz) at 30 dB		
	A3	Bandwidth (kHz) at 60 dB		
	A4	Intermediate-frequency rejection ratio (dB)		
	A5	Rejection ratio for image and other spurious responses (dB)		
	A6	Variation of group-delay time (ms)		
Two-signal selectivity	B1	Level of unwanted signal for 3 dB blocking (dB (μV)) (blocking)		
		Adjacent-signal selectivity:		
	B2	Level of unwanted signal with wanted signal level		20 dB (μV)
	B3			60 dB (μV)
	B4			as specified
Three-signal selectivity (inter-modulation)	C1	Level of two unwanted signals for intermodulation as indicated in notes in the following sections and for wanted signal as stated here	$F_n' + F_n'' = F_{if}$	20 dB (μV)
	C2			60 dB (μV)
	C3		$F_n' - F_n'' = F_{if}$	20 dB (μV)
	C4			60 dB (μV)
	C5		$F_n' + F_n'' = F_d$	20 dB (μV)
	C6			60 dB (μV)
	C7			as specified
	C8		$F_n' - F_n'' = F_d$	20 dB (μV)
	C9			60 dB (μV)
	C10		$2F_n' - F_n'' = F_d$	20 dB (μV)
	C11			60 dB (μV)
	C12			as specified
Sensitivity	D1	Noise factor (dB)		
	D2	Reference sensitivity (dB (μV)) for output conditions specified		
	D3	Automatic gain control: output variation (dB)		
Miscellaneous	E1	Tuning stability for conditions specified		
	E2	Spurious emissions		
	E3	Frequency setting-error (kHz)		

1.2 *General notes related to the lines of the preceding list of characteristics* (Additional notes for different services or types of emission are attached to the subsequent appropriate tables)

A1 to A3 See § 1 and § 4.1 of Recommendation 332–1.

A4 See § 4.4 of Recommendation 332–1.

A5 See § 4.3 and § 4.5 of Recommendation 332–1.

A6 See Recommendation 328–1. The variation is that within the range of modulation frequencies used.

B1 to B4 C1 to C12 D2 and D3	For receivers with incorporated antennae, dB (μV) should be replaced by dB (μV/m).
	Unless otherwise specified, the levels of wanted and unwanted signals are given as the e.m.f. in dB (μV) for a source impedance of 75 Ω; if a receiver is designed to work from a source impedance other than 75 Ω, the e.m.f. is that which corresponds to the same available power (see Recommendation 331-1, § 5).
B1 to B4	The separation between the wanted and unwanted signals is the channel spacing if there is a recognized value; otherwise see the note to the appropriate table.
B1	See § 6.2 of Recommendation 332-1. For level of wanted signal see appropriate table of this Study Programme.
B2 and B3	See § 6.3 of Recommendation 332-1.
C1 to C12	See § 6.4 of Recommendation 332-1 except § 6.4.5.
D1	See § 2 of Recommendation 331-1.
D2	See § 4 of Recommendation 331-1.
D3	For ranges of input variation see appropriate Table.
E1	For conditions, see appropriate Table.
E2	" Oscillator level at input (dB (μV)) across a dummy antenna or specified source resistance. See Report 193-1, § 2. "
E3	For tunable receivers, measured under normal operating conditions.

1.3 *Tables of characteristics to be recorded for receivers typical of the categories used for the fixed service*

Notes common to the different categories of receiver used in the fixed service, supplement the notes in § 1.2.

The values recorded will be the worst value over the specified range of frequencies.

The values for tuning stability will be the worst of the following:

- frequency variation for + 10% change in supply voltage;
- frequency variation for — 10% change in supply voltage;
- frequency variation for 10° C change of temperature within the range + 5° C to + 40° C.

1.3.1 *Fixed service telegraph and facsimile receivers – Bands 1605 to 30 000 kHz*

For A7A, A7B, A4A and F4, refer to the end of this section.

Characteristics	F1 (for 400 Hz frequency shift)		F6 (for 400 Hz spacing between frequencies)	
	Typ.	Min.	Typ.	Min.
A1 to A3, A4, A5 B2, B3 C1 to C6 C8 to C11 D1, D2 E1, E2				

Notes:

A1 to A3	Bandwidth adjusted to suit frequency shift or spacing.
B2, B3	The level of the unwanted F1 signal with 400 Hz shift at a spacing of 10 kHz that increases the distortion of the wanted signal to 20% or increases the element error-rate to 1 in 1000.

C1 to C6, C8 to C11	The level of two unwanted signals, one unmodulated and one being of type F1, that increases the distortion of the wanted signal to 20%, or increases the element error-rate to 1 in 1000.
D2	The level of the input signal that gives a distortion of the output of 20% with an error-rate of 1 in 1000.
E1	The residual frequency error Hz with automatic frequency control in operation.

N.B. – The values are for wanted and unwanted signals with slightly different keying speeds of about 100 bauds or 200 bauds using Q9S code, or other non-rhythmic code, i.e. not reversals (see Question 1/II footnote). The measurements made at 100 and 200 bauds will be given in separate tables of values.

For A7A and A7B emissions the receivers used are the same as for A3B in Table 1.3.2 which includes a line for the group-delay variations (ms) within the modulation frequency range 425 to 2805 Hz.

For A4A or F4 emissions no tables are given, because these emissions are received on A3B or F1 type receivers, but see Recommendation 344–1 (Volume III) for the frequency stability required.

1.3.2 *Fixed service telephony receivers – bands 1605 to 30 000 kHz*

Characteristics	A3A		A3B		A3J	
	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1, A4, A5, A6 B1, B2, B3 C1 to C6 C8 to C11 D1, D2, D3 E1, E2						

Notes:

The telephony receivers used for A3B emissions must be designed for a 12 kHz bandwidth.

A1	Bandwidth including all the sideband channels.
A6	Concerns receivers used for emissions A7A or A7B.
B1	For a wanted signal level of 60 dB (μV). The wanted and the unwanted signal are 10 kHz apart.
B2, B3	The level of the unwanted A2 signal with 30% modulation at 400 Hz, 10 kHz from the carrier of A3A or A3B or from the nominal carrier frequency of A3J, that produces an output 20 dB below that of a 1000 Hz output produced by a wanted sideband signal of the level shown being 6 dB below the peak sideband level, and accompanied by a carrier of the appropriate level in the case of A3A and A3B.
C1 to C6, C8 to C11	The level of two unwanted signals, one unmodulated and one being of type A2 with 30% modulation at 400 Hz that gives an output 20 dB below that due to a wanted sideband signal of the level shown, being 6 dB below the peak sideband level, and accompanied by a carrier of the appropriate level in the case of A3A and A3B.

D2 The level of the sideband input signal being 6 dB below the peak sideband level, and accompanied by a carrier of the appropriate level in the case of A3A and A3B, that gives an output signal-to-noise ratio of 20 dB.

D3 For input signal range 0 to 80 dB (μV).

E1 The residual frequency-error (Hz) with the automatic frequency control in operation.

N.B. – The Note to E1 does not apply to A3J, but see Recommendation 349–1.

1.4 *Tables of characteristics to be recorded for receivers typical of the categories used for mobile services*

General Notes, common to the different types of receivers used in the mobile services, to supplement the Notes in § 1.2.

The values recorded will be the worst value over the specified range of frequencies.

A1 Bandwidth of the linear part of the receiver; with the receiver set as closely as possible to 1 kHz for A1, 3 kHz for A2 and to 6 kHz for A3 classes of emission (below 30 MHz).

B1 For a wanted signal level equal to the reference sensitivity level (see D2).

B4 Level of unwanted signal (dB (μV)) increasing the noise output by 6 dB. Wanted signal at the reference sensitivity level (see D2). Unwanted signal of the same type as the wanted signal. Frequency spacing between channels 7 kHz below 30 MHz for class A3. In the other cases the channel spacing would be that for which the receiver is designed.

C7 Same as for B4, but with two unwanted signals, with frequencies close to, but not equal to, half the wanted signal.

C12 Same as for B4, but with two unwanted signals. One unwanted signal is in the adjacent channel, and the other in the next channel.

D2 Input signal level (dB (μV)) for a signal-to-noise ratio of 12 dB at the output, the output signal (1 kHz) being filtered out (see § 11, Recommendation 331–1). Degree of modulation 30% for A2 and A3, 70% for F3. Dummy antenna 10 Ω + 300 pF below 4 MHz, 75 Ω between 4 and 30 MHz, 50 Ω above 30 MHz.

D3 Increase in output level (dB) for an increase at the input of 40 dB above the sensitivity level.

Facsimile is under consideration by Study Group XIII and at present is not shown in the Tables.

1.4.1 *Maritime mobile service – ships main receivers – band 14 – 535 kHz*

Characteristics	A1 Aural		A2 Aural	
	Typ.	Min.	Typ.	Min.
A1 to A5 C12, D2, E3				

Note:

C12 $F_d = 500$ kHz, $F_n' = 520$ kHz;
$F_n'' = 540$ kHz
(frequency adjusted to give maximum interference).

1.4.2 *Maritime mobile service – coast station receivers – band 14 – 535 kHz*

Characteristics	A1 Aural		A2 Aural	
	Typ.	Min.	Typ.	Min.
A1 to A5 C12, D2, E3				

Note:

C12 F_d = 500 kHz, F'_n = 520 kHz;
F''_n = 540 kHz
(frequency adjusted to give maximum interference).

1.4.3 *Maritime mobile service – ships main receivers – band 1605 – 28 000 kHz*

Characteristics	A1 Aural		A2 Aural		A3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 to A5, B1, B4 C7, D2, D3, E3						

Notes:

B4 Unwanted signal modulated with 400 Hz for A2 and A3
C7 F_d = 2182 kHz, F_n = 1082 kHz;
F''_n = 1100 kHz
B1, B4 and D3 applicable only for A3.

1.4.4 *Maritime mobile service – coast station receivers – band 1605 – 28 000 kHz*

Characteristics	A1 Aural		A2 Aural		A3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 to A5, B1, B4 C7, D2, D3, E3						

Notes:

B4 Unwanted signal modulated with 400 Hz for A2 and A3
C7 F_d = 2182 kHz, F'_n = 1082 kHz;
F''_n = 1100 kHz
B1, B4, and D3 applicable only for A3.

1.4.5 *Maritime mobile service – telephony receivers – band 1605 – 3600 kHz*

Characteristics	A3		A3J	
	Typ.	Min.	Typ.	Min.
A1 to A5, B1 B4, C7 D2, D3, E3				

Notes:

B4 Unwanted signal modulated with 400 Hz for A3, and unmodulated and adjusted within the adjacent channel to give maximum interference for A3J.

C7 $F_a = 2182$ kHz, $F'_n = 1082$ kHz;
$F_n = 1100$ kHz.

1.4.6 *Maritime mobile service – telephony receivers – band 3600 – 28 000 kHz*

Characteristics	A3		A3J	
	Typ.	Min.	Typ.	Min.
A1 to A5, B1 B4 D2, D3, E3				

Note:

B4 Unwanted signal modulated with 400 Hz for A3, and unmodulated and adjusted within the adjacent channel to give maximum interference for A3J.

1.4.7 *Maritime mobile service – ships main receivers – band 156 – 174 MHz*

Characteristics	A3		F3	
	Typ.	Min.	Typ.	Min.
A1, A4, A5 B4, C12 D2, D3, E1, E2				

Notes:

B4 Unwanted signal modulated with 400 Hz *.

C12 Signals F'_n and F_n unmodulated. The difference ($F''_n \sim F'_n$) will be adjusted to give maximum interference.

E1 Worst value of the following: degradation of adjacent channel selectivity (see B2, § 1.1) for + 10% change in supply voltage, for — 10% change in supply voltage or for a change of temperature from + 5° C to + 40° C.

1.4.8 *Maritime mobile service – coast station receivers – band 156 – 174 MHz*

Characteristics	A3		F3	
	Typ.	Min.	Typ.	Min.
A1, A4, A5 B4, C12 D2, D3, E1, E2				

Notes:

B4 Unwanted signal modulated with 400 Hz *.

C12 Signals F'_n and F''_n unmodulated. The difference $(F''_n \sim F'_n)$ will be adjusted to give maximum interference.

E1 worst value of the following: degradation of adjacent channel selectivity (see B2, § 1.1) for + 10% change in supply voltage, for — 10% change in supply voltage or for a change of temperature from + 5° C to + 40° C.

1.4.9 *Land-mobile service – frequencies above 25 MHz*

Characteristics	Band 25–100 MHz				Band 100–300 MHz				Frequencies over 300 MHz	
	A3		F3		A3		F3		F3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1, A4, A5 B4, C12 D2, D3, E1 E2										

Notes:

B4 Unwanted signal modulated with 400 Hz *.

C12 Signals F'_n and F_n unmodulated. The difference $(F''_n \sim F'_n)$ will be adjusted to give maximum interference.

E1 Worst value of the following: degradation of adjacent channel selectivity (see B2, § 1.1) for + 10% change in supply voltage, for — 10% change in supply voltage or for a change of temperature from — 25° C to + 55° C.

2. Monochrome television broadcasting

Note. – Agreed values of phase correction, minimum field strength and protection ratio are given in Recommendations 266, 417–1 and 418–1.

* Modulation 30% for A3, 70% for F3.

2.1 *List of characteristics*

Selectivity		A1	System
Selectivity	Attenuation (dB) at	B1	— 3·5 MHz
		B2	— 2·5 MHz
		B3	— 2 MHz
		B4	— 1·5 MHz
		B5	— 1·25 MHz
		B6	— 1 MHz
		B7	— 0·5 MHz
		B8	0 MHz
		B9	+ 1 MHz
		B10	+ 2 MHz
		B11	+ 2·5 MHz
		B12	+ 3 MHz
		B13	+ 3·5 MHz
		B14	+ 4 MHz
		B15	+ 4·5 MHz
		B16	+ 4·75 MHz
		B17	+ 5 MHz
		B18	+ 5·5 MHz
		B19	+ 6 MHz
		B20	+ 6·5 MHz
		B21	+ 7 MHz
		B22	+ 8 MHz
		B23	+ 9 MHz
		B24	+ 11·15 MHz
		B25	Image rejection ratio (dB)
		B26	Intermediate-frequency rejection ratio (dB)
		B27	Rejection ratio for other spurious responses (dB)
Sensitivity		C1	Noise factor (dB)
		C2	Sensitivity (dBmW)
		C3	A.g.c. characteristic (dB)
		C4	Maximum usable input signal level (dBmW)
Stability		D1	Frequency drift during heating-up period (kHz)
		D2	Frequency change for a supply voltage variation of ± 10% (kHz)
Distortion		E1	Modulation-frequency response (dB)
		E2	Unit-step response: rise-time (ns)
		E3	Unit-step response: overshoot (%)
		E4	Frame frequency square-wave response (%)
		E5	Group delay (total spread) (ns)
Miscellaneous		F1	V.s.w.r.
		F2	Balance ratio (dB)
		F3	Black-level shift (%)
Sound channel		G1	6 dB passband (kHz)
		G2	Sensitivity (dBmW)

2.2 *General notes to list of characteristics of monochrome television receivers*

The procedure to be followed is that recommended by the I.E.C. in Publication 107 and its revision.

A1

Identification of the system by the appropriate letter designator used by the C.C.I.R. in Report 308–1.

B1 to B24

The reference frequency is that corresponding to the picture carrier, and the reference level is that of the picture carrier frequency. The frequencies listed include the sound carrier and the adjacent-channel sound and picture carrier for all of the systems. Entries are not required for frequencies not pertinent to the particular system. For System A (405 lines) reverse the polarity signs.

B26, B27, B28

The value for the channel of the receiver at which the *poorest* performance is found.

C1

The *average* for the several channels of the receiver in the indicated frequency band.

C2

Sensitivity for a given channel of a receiver will be taken as the higher of the signal levels required to satisfy either the gain-limited or the noise-limited sensitivity measurement. The value reported is to be the *average* of such sensitivity for all the channels of the receiver in the frequency band in question. The gain-limited sensitivity is the input level necessary to provide a 20 V video signal at the picture tube. The noise-limited sensitivity is the input level necessary for a signal-to-noise ratio of 30 dB at the picture tube.

C3

Variation in output level for an input level change from — 20 dBmW to — 50 dBmW.

D1

The value to be given is the difference between the highest and the lowest local oscillator frequency observed during the period from 2 minutes to 60 minutes after switching on, for the *worst* channel in the pertinent frequency range.

D2

The larger of the frequency variations caused by a 10% increase or decrease in the supply voltage, for the *worst* channel in the pertinent frequency range.

E1

The maximum difference (in dB) of response to modulation frequencies between 100 kHz and the upper nominal video frequency limit for the system.

E2

Time taken to pass from 10% to 90% of final amplitude of the signal.

E4

Maximum variation (%) of the level of the normally flat top of a square wave having a repetition frequency equal to the frame frequency of the system (I.E.C. Publication 107, Clause 5.4).

E5

Difference between the maximum and minimum group-delay with frequency for the overall receiver.

F1

Relative to design value of input impedance.

F2

For receivers intended for symmetrical input.

F3

For receivers with d.c. restoration.

G2

Same as note for C2 except that a standard audio output power (500 mW or 50 mW) or an audio signal-to-noise ratio of 30 dB is required. The output power chosen should be stated and should bear a reasonable relation to the maximum output.

2.3 *Tables*

A1 System	Bands I and III								Bands IV and V							
	A		B		C		etc.		G		H		I		etc.	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
B1 B2 etc. G2																

3. Sound broadcasting

Note. – Agreed values concerning frequency-modulation broadcasting (pre-emphasis, frequency deviation, minimum field strength and protection ratios) are given in Recommendation 412. For amplitude-modulation broadcasting see Report 399 and Recommendation 449.

3.1 *List of characteristics*

Selectivity	Single-signal	A1 A2 A3 A4 A5 A6 A7 A8	Passband at 6 dB points (kHz) Attenuation, dB at $\pm 1\ d$ Attenuation, dB at $\pm 2\ d$ Attenuation, dB at $\pm 4\ d$ Attenuation, dB at $\pm 8\ d$ Image rejection ratio (dB) Intermediate-frequency rejection ratio (dB) Rejection of other spurious responses (dB)
	Two-signal	A9 A10 A11 A12	Level of unwanted signal at $\pm 1\ d$ (dB (μV) Level of unwanted signal at $\pm 2\ d$ (dB (μV) Level of unwanted signal at $\pm 3\ d$ (dB (μV) Level of unwanted signal at $\pm 4\ d$ (dB (μV)
Sensitivity		B1 B2	Sensitivity (dB (μV) Automatic gain control characteristic (dB)
Stability		C1 C2	Frequency drift during heating-up (kHz) Frequency shift due to $\pm$ 10% change in supply voltage (kHz)
Miscellaneous		D	Mains interference ratio

3.2 *Notes to lines of characteristic list*

The measurement procedure to be followed is that recommended by the I.E.C. in Publications 69 and 91 and their revisions, except that signal levels for all classes of receiver are given in dB (μV), whereas the present I.E.C. publications use dBmW for F3 receivers.

A2 to A5

$d = 9$ kHz for A3 (except where other channel spacings are used) and 100 kHz for F3.

A6 to A8

For the signal frequency at which the poorest performance occurs in the indicated frequency band.

A9 to A12

The level of the wanted signal is 10 dB higher than the sensitivity level (see the note below for line B1). The level of the unwanted signal is that which causes a signal-to-interference ratio of 30 dB for A3 or 40 dB for F3. For A3, $d = 9$ kHz (except where other channel spacings are used) and 100 kHz for F3. This procedure is included provisionally until the I.E.C. develops standard procedures stating the wanted signal level.

B1

The sensitivity is the higher of the two input levels required to satisfy the gain-limited or noise-limited sensitivity measurement. Gain-limited sensitivity is the input level required to produce an audio output of 500 mW. Noise-limited sensitivity is the input level required to produce a signal-to-noise ratio of 30 dB for A3 or 40 dB for F3. The value to be reported is the average of such sensitivity values measured over the indicated frequency range. For A3 receivers the level is in dB (μV) in series with the appropriate artificial antenna. For F3 receivers the level is in dB (μV) at 75 ohms; if the actual source resistance is other than 75 ohms the e.m.f. reported should be that which corresponds to an available power at 75 ohms equal to that of the actual e.m.f. and source resistance. For receivers with integral antennae, the levels are to be given in dB (μV)/m.

B2

The change in output level (dB) for an input level change from 40 to 100 dB (μV) for A3, 30 to 90 dB (μV) for F3, and 40 to 100 dB (μV/m) for A3 or F3 receivers with integral antenna.

C1

The difference between the highest and lowest frequencies observed between 2 min and 60 min of switching on (may only be significant for receivers with indirectly heated tubes). For the channel with *poorest* performance in the indicated frequency range.

C2

The larger of the frequency changes resulting from a ± 10% change in supply voltage for the channel with the *poorest* performance in the indicated frequency range.

D

The ratio in dB of the interference voltage on the mains supply line to the voltage at the receiver input giving the same response. The measurement should be made at a frequency of 1 MHz using the artificial network corresponding to an effective earth connection of 2 m. The test applies for A3 only. (See I.E.C. Publication 69, Clause 18 and later revisions.)

3.3 *Tables*

3.3.1 *Ordinary domestic receivers*

Characteristics	A3								F3	
	150–285 kHz		525–1605 kHz		2300–5060 kHz		5950–26 100 kHz			
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1, A2, A3 etc.										

3.3.2 *Vehicular receivers*

Characteristics	A3								F3	
	150–285 kHz		525–1605 kHz		2300–5060 kHz		5950–26 100 kHz			
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1, A2, A3 etc.										

Note. – " Portable " receivers have not been included as a separate class of receiver since this description covers a variety of receivers with performance figures varying over a large range. It is recognized that portable receivers are very widely used and that some of them may be regarded as home receivers. Results for a defined class of portable receivers may be submitted by an Administration if it is considered that planning of broadcast services in certain areas may be required to take into account the performance of such receivers. This consideration is, however, unlikely to apply to very small receivers (pocket transistor receivers, etc.).

In test B1, a 50 mW audio-frequency output power should be used instead of 500 mW, if 500 mW is unreasonable in relation to the maximum output.

4. Spurious emissions from broadcast and television receivers

4.1 *Table*

				Frequency of spurious emissions	Type or system of receiver: Monochrome television; system: A	B	etc.	Sound broadcasting: A3	F3
Frequencies below 30 MHz	Injected voltage in dB (μV) including television time-base harmonics, and emission of oscillator, intermediate-frequency and other frequencies from television and amplitude-modulation receivers	Into the mains	Unbalanced	A1 150 - 500 kHz A2 500 - 1605 kHz A3 1605 kHz–4 MHz A4 4 - 10 MHz A5 10 - 30 MHz					
			Balanced	A6 150 - 500 kHz A7 500 - 1605 kHz A8 1605 kHz–4 MHz A9 4 - 10 MHz A10 10 - 30 MHz					
		Into the antenna (AM receivers only)		A11 150 - 500 kHz A12 500 - 1605 kHz A13 1605 kHz–4 MHz A14 4 - 10 MHz A15 10 - 30 MHz					
	Radiation from television receiver time-base circuits*	Electric in dB (μV/m)		B1 150 - 500 kHz B2 500 - 1605 kHz					
		Magnetic n dB (μV/m)		B3 150 - 500 kHz B4 500 - 1605 kHz					
Frequencies abov 30 MHz	Radiation of local oscillator and its harmonics, intermediate-frequency and other spurious emissions (dB (μV/m)			C1 30 - 50 MHz C2 50 - 100 MHz C3 100 - 200 MHz C4 200 - 300 MHz C5 300 - 500 MHz C6 500 - 1000 MHz					

4.2 *Notes to Table 4.1*

Measurements should be made in accordance with I.E.C. Publications 106, 106A and their revisions (see Recommendation 239). If measurements are made at distances other than those specified by I.E.C. and a median correlation factor is known, the values should be given for the I.E.C. distance and the actual distance and correlation factor employed should be stated.

The value reported in each frequency range of the table should be that of the strongest spurious emission found in such range when the receiver is operated on any of its available channels.

Tests on all types of sound and television receivers, including portables, should be made.

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* The C.I.S.P.R. has not found it necessary to fix limits for these measurements.

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LIST OF DOCUMENTS OF STUDY GROUP II (PERIOD 1963-1966)

Doc.	Origin	Title	Reference
II/1	United States of America	Revision of Report 183 – Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	Q. 175
II/2	United Kingdom	Diversity reception for the relaying of broadcasting in the high frequency bands	Q. 225
II/3 (III/7)	United States of America	Diversity techniques for HF radiotelegraphy	Q. 225, Q. 3(III) S.P. 3A(III)
II/4	Sweden	Sensitivity, noise factor and selectivity of receivers-Assessment of stability of a receiver	Q. 228, 229, 231
II/5	United Kingdom	Spaced-antenna reception of HF SSB radiotelephone signals	Q. 225
II/6	People's Republic of Poland	Distortion in frequency-modulation receivers due to multipath propagation	Q. 177
II/7	People's Republic of Poland	Receiver selectivity	Q. 229
II/8	Japan	Improvement of the effective selectivity of a radio receiver by using a radio-frequency crystal filter	Q. 229
II/9	U.S.S.R.	Diversity reception under conditions of multipath propagation – The effect of receiver channel unbalance and gain differences in diversity reception on resistance to interference from telegraph signals with ionospheric scatter	Q. 225
II/10	U.S.S.R.	Draft Report – Diversity reception under conditions of multipath propagation	Q. 225
II/11	U.S.S.R.	Tuning stability of receivers – Angular modulation of local oscillator voltages	Q. 230
II/12	U.S.S.R.	Definition of basic parameters for radio reception systems	Q. 228, S.P. 185
II/13	U.S.S.R.	Measurement of some receiver parameters	Q. 177, S.P. 185
II/14	U.S.S.R.	Revision of Report 183 – Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	Q. 175
II/15	Study Group II	Interim Report by the Chairman – Receivers	
II/16	Working Group II/1	Report on the progress achieved by 1 April, 1965	S.P. 185
II/17 (I/15)	C.I.S.P.R.	Report to the C.C.I.R. on the proceedings of the 1964 (C.I.S.P.R.) meeting in Stockholm	Op. 2, Rec. 334 Rep. 182, 183 Q. 227(I) S.P. 227B(I)
II/18	Federal Republic of Germany	Spurious emissions from receivers excluding sound-broadcast and television	Q. 176

Doc.	Origin	Title	Reference
II/19 and Rev. 1	Federal Republic of Germany	Tuning stability of receivers	Q. 230
II/20	F. R. of Germany	Sensitivity and noise factor	Q. 228
II/21	F. R. of Germany	Typical receivers	S.P. 185
II/22	F. R. of Germany	Selectivity of receivers	Q. 229
II/23	F. R. of Germany	Diversity reception under conditions of multipath propagation	Q. 225
II/24	C.C.I.R. Secretariat	Submission of Docs. XI/76 and X/108	
II/25	Italy	Television community systems	Recs. 239, 330
II/26	Italy	Diversity reception at microwave frequencies	Q. 225, § 3
II/27	Study Group II	Summary record of the first meeting	
II/28	C.C.I.R. Secretariat	Submission of Doc. X/2 – E.B.U. – An objective two-signal measuring method for determining the radio-frequency protection ratios for amplitude-modulated sound broadcasting	
II/29 (V/41) (I/19)	Study Groups I, II, V	Summary record of the joint opening session	
II/30 (XI/122)	O.I.R.T.	Required selectivity of television receivers with establishment of protection ratios adopted for network planning	Q. 229, S.P. 185, Q. 267
II/31	C.C.I.R. Secretariat	Submission of Doc. X/III: Draft Rec. Amplitude-modulation sound broadcasting RF protection ratio curve	Q. 262(X)
II/32	Working Party II-2-A	Draft Report – Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	Q. 175, § 1
II/33	Working Party II-2-A	Report 185	
II/34 and Add. 1, and Add. 2	Working Party II-2-A	Draft – Amendments to Recommendation 332	
II/35 and Add. 1, and Add. 2	Working Party II-2-A	Draft – Amendments to Recommendation 332	
II/36 and Corr. 1	Working Party II-2-B	Draft Report – Diversity reception	Q. 225
II/37 and Rev. 1	Working Party II-2-B	Report 190	
II/38 and Rev. 1	Working Party II-2-B	Report 193	
II/39	Working Group II-2	Draft Report – Cross-modulation in transistorized FM receivers	Q. 229, § 5
II/40	Working Party II-1-C	Typical receivers	S.P. 185
II/41	Working Group II-2	Amendments to Report 188	
II/42	Working Party II-2-A	Proposed amendments to Report 186	
II/43	Working Party II-2-A	Proposed amendments to Report 192	

Doc.	Origin	Title	Reference
II/44	Working Party II-2-A	Draft Report – Characteristics of radio-relay receivers in the 2 – 10 Gc/s band	S.P. 185
II/45	Study Group II	Summary record of the second meeting	
II/46 and Rev. 1	Working Group II-1	Typical receivers – Draft amendment to the text of the operative part of Study Programme 185(II)	S.P. 185
II/47	Working Group II-1	Typical receivers – Draft amendments to the text of the Annex to the Operative part of Study Programme 185(II)	S.P. 185
II/48	Working Group II-1	Draft Report – Values for the characteristics of typical receivers for the fixed service	S.P. 185
II/49	Working Group II-1	Draft Report – Values for the characteristics of typical receivers for the mobile service	S.P. 185
II/50	C.C.I.R. Secretariat	List of documents issued (II/1 to II/52)	
II/51	Study Group II	Summary record of the third meeting	
II/52	C.C.I.R. Secretariat	List of participants	
II/53	U.S.S.R.	Selectivity of receivers – The dispersion of tube parameters as a source of spurious reception in frequency converters	Q. 229
II/54	Italy	Development of design methods to improve selectivity of VHF/MF service receivers	Q. 229
II/55	Italy	Measurement of stability in portable MF receivers	Rec. 333 Q. 230
II/56	Italy	Steps to ensure the best selectivity and stability characteristics in HF receivers for the fixed service	Q. 229, 230
II/57 (XI/137)	Italy	Television community systems	Rec. 239, 330
II/58	Sweden	Swedish comments to texts emanating from the interim meeting of Study Group II, Geneva, 1965	
II/59 (V/106) (IX/210)	Italy	Propagation on line-of-sight paths	Q. 311(V), 298(IX)
II/60 (I/47)	U.S.S.R.	Description and technical parameters of a reference oscillator	S.P. 183(I), Q. 230
II/61	U.S.S.R.	Typical receivers – Freedom from noise of mains-supply broadcast receivers with special reference to the power-feed circuit	Draft S.P.
II/62 (III/105)	U.S.S.R.	Sensitivity and noise factor – A method of measuring static characteristics of radiotelegraph receivers	Q. 228
II/63	U.S.S.R.	Determination of basic parameters for radio receiving systems	Q. 228
II/64	U.S.S.R.	Polarization-diversity reception and the assessment of its efficiency	Q. 225
II/65	U.S.S.R.	Typical receivers – Characteristics of sound broadcasting receivers	S.P. 185
II/66	U.S.S.R.	Typical receivers – Parameters of portable transistorized sound broadcasting receivers	S.P. 185

Doc.	Origin	Title	Reference
II/67	United States of America	Proposed modifications to Draft Report B.k(II) – Diversity reception	Draft Rep.
II/68	United States of America	Values for the characteristics of typical receivers	Draft S.P.
II/69 and Add. 1	Chairman, S.G. II	Report by the Chairman – Receivers	
II/70	Japan	Proposed modifications to Draft Recommendation B.a(I)	Draft Rec.
II/71	Japan	Proposed modifications to Draft Study Programme B.r(II)	Draft S.P.
II/72	Japan	Typical receivers – Some typical values for telegraph receivers	Draft S.P. Draft Rep.
II/73	P.R. of Poland	Multi- path propagation distortion in FM receivers	Draft Q.
II/74	Italy	Remote-controlled HF receiver for unattended receiving station	Rec. 333, Q. 230
II/75 (III/112)	U.S.S.R.	Design of the reception channel of an ionospheric-scatter link	Rec. 338
II/76	Study Group II	Summary record of the first meeting	
II/77	Working Group II-A	Proposed amendments to Draft Report B.f(II) – Criteria for receiver tuning	
II/78	Working Group II-A	Proposed amendments to Draft Report B.g(II) – Suppression of amplitude-modulation (caused by multi- path propagation) in FM receivers	
II/79 and Rev. 1	Working Group II-A	Draft revision of Question 228(II) – Sensitivity and noise factor	
II/80	Working Group II-A	Proposed amendments to Draft Report B.c(II)	
II/81	Working Group II-A	Proposed amendments of Draft Recommendation B.a(II) – Noise and sensitivity of receivers	
II/82 and Add. 1	Working Group II-A	Draft amendments to Draft Report B.k(II) Diversity reception	
II/83	Working Group II-A	Proposed amendments to Draft Recommendation B.b(II) – Selectivity of receivers	
II/84	Working Group II-A	Draft note submitted by Sub-Group II-A-2 for insertion in the final report of the Chairman of Study Group II – Community aerials for sound broadcast and television	
II/85	Working Group II-A	Draft revision of Question 229(II) – Selectivity of receivers	
II/86	Working Group II-A	Draft Question – Remote controlled HF receiving stations	
II/87	Working Group II-B	Proposed amendment to Draft Report B.m(II) – Characteristics of radio-relay receivers	
II/88	Working Group II-B	Proposed amendments to Draft Report B.n(II) – Values for the characteristics of typical receivers for the fixed service	

Doc.	Origin	Title	Reference
II/89	Working Group II-B	Proposed amendments to Draft Report B.p(II) – Values for the characteristics of typical receivers for the mobile service	
II/90	Working Group II-B	Proposed amendments to Draft Study Programme B.r(II) – Typical receivers	
II/91	Working Group II-A	Draft Report – Remote controlled receiving stations	
II/92	Working Group II-A	Draft Report – Stability measurement of portable receivers	Q. 231
II/93	Working Group II-A	Proposed amendments to Draft Report B.d(II) – Selectivity of receivers	
II/94	Working Group II-A	Draft note submitted by Sub-Group II-A-1 for final report of the Chairman of Study Group II – Dynamic range of a receiver	
II/95	Study Group II	Report – Values for the characteristics of typical receivers for sound and monochrome television broadcasting	Draft S.P.
II/96	Working Group II-A	Proposed amendments to Draft Report B.h(II)	
II/97	Study Group II	Summary record of the second meeting	
II/98	Study Group II	Summary record of the third meeting	
II/99	Study Group II	Summary record of the fourth meeting	
II/100	C.C.I.R. Secretariat	List of documents issued (II/53 to II/101)	
II/101	Study Group II	Status of texts	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP II

Doc.	Title	Final text
II 1001	Distortion in frequency-modulation receivers due to multipath propagation	Q. 9/II
II 1002	Remotely controlled HF receiving stations	Q. 8/II
II 1003	Spurious emissions from receivers	Rep. 193–1
II/1004	Criteria for receiver tuning – Criteria to be used in measurements of tuning stability	Rep. 188–1
II/1005	Tuning stability of receivers	Rep. 192–1
II/1006	Diversity reception	Rep. 327
II/1007	Cross-modulation in transistorized FM receivers	Rep. 328
II/1008	Characteristics of radio-relay receivers	Rep. 334
II/1009	Values for the characteristics of typical receivers for the fixed service	Rep. 331
II/1010	Values for the characteristics of typical receivers for the mobile service	Rep. 332
II/1011	Remote controlled receiving stations	Rep. 329
II/1012	Stability measurement of portable FM receivers	Rep. 330
II/1013	Values for the characteristics of typical receivers for sound and monochrome television broadcasting	Rep. 333
II/1014	Sensitivity and noise factor	Q. 1/II
II/1015	Selectivity of receivers	Q. 3/II
II/1016	Noise and sensitivity of receivers	Rec. 331–1
II/1017	Selectivity of receivers	Rec. 332–1
II/1018	Multiple-signal method of measuring selectivity	Rep. 186–1
II/1019	Suppression of amplitude-modulation (caused by multipath propagation) in FM receivers	Rep. 190–1
II/1020	Selectivity of receivers	Rep. 185–1
II/1021	Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	Rep. 183–1
II/1022	Typical receivers	S.P. 11A/II
II/1023	List of documents issued (II/1001 to II/1023)	

RECOMMENDATIONS OF SECTION K (VOCABULARY)

RECOMMENDATION 430 *

UNIT SYSTEMS **

The C.C.I.R., (1953 – 1963)

CONSIDERING

(a) that the use of the rationalized MKS 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

(Question 73)

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,

* This Recommendation replaces Recommendation 143.

** *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".

and that as early as 1937 the I.E.C. adopted the hertz (symbol: Hz) as a name for the unit of frequency (see, *inter alia*, Publication 27, 1966);

(b) that the C.C.I.T.T. also uses the hertz (see Red Book, French version);

(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 $0{\cdot}3 \times 10^N$ 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 8 : VHF
band 5 : LF	band 9 : UHF
band 6 : MF	band 10 : SHF
band 7 : HF	band 11 : EHF

REPORTS OF SECTION K (VOCABULARY)

REPORT 321 *

TERMS AND DEFINITIONS

Right-hand (clockwise) or left-hand (anti-clockwise) elliptically or circularly 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: No. 51 009 and 51 010; – Institution of Radio Engineers 1950; – International Electrotechnical Commission, Draft 1/60 (Secretariat) 281: No. 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 355 *

GENERAL GRAPHICAL SYMBOLS FOR TELECOMMUNICATION

(Resolution 23)

(1966)

1. The Joint C.C.I./I.E.C. Committee for the preparation of a publication for the international standardization of general graphical symbols for telecommunication 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 C.C.I./I.E.C. Working Party on graphical symbols for telecommunication has Mr. Anderson (United Kingdom) as Chairman, and Mr. Bondesson (Sweden) as Secretary. The Working Party comprises 12 members, six representing the I.E.C., 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. Aubert (France)**,

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 C.C.I.R. Study Group XIV, are limited to those symbols which are of direct interest to the work of the C.C.I.R.

4. **Documents presented to the XIth Plenary Assembly, Oslo, 1966**

Docs. XIV/2, 5, 9 (C.C.I.R. Secr.); XIV/4 (F.R. of Germany); XIV/8 (O.I.R.T.)

5. The results of the work done by the Joint Working Party are given in Doc. XIV/9, 1963–1966. Study Group XIV agrees generally with the proposed symbols. As many of the symbols in this document were considered again in June 1966 by this Working Party and, as the final amendments have not yet been made known to the C.C.I.R., it is considered that not all of the symbols of Doc. XIV/9 are, at present, ready for acceptance by the C.C.I.R.

6. Study Group XIV considers that the object of this work is the publication by the I.E.C. 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 Annex to this Report contains a preliminary list of such symbols as are acceptable for this Recommendation.

7. Approval of symbols published by the I.E.C. 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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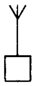
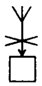
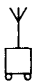
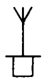
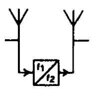
* This Report was adopted unanimously.

** Mr. Aubert, having advised his inability to fuefill this function, and the French Administration not having been able to nominate a successor, other Administrations are invtted to nominate a successor to Mr. Aubert.

ANNEX

Symbols for radio stations

No.	Symbol	Description
		General Note: Symbols for radio stations are formed by using an appropriate symbol for an antenna with appropriate complementary symbol(s) added at the base of the antenna symbol
1		Radio station. *General symbol* *Note 1.* – A suitable symbol may be inserted in the square to indicate the character of the station e.g. T = Telegraph
		Qualifying symbols indicating emission and/or reception
2.1		Emission
2.2		Reception
2.3		Alternative emission and reception
2.4		Simultaneous emission and reception
		Examples:
3		Transmitting and receiving radio station (simultaneous emission and reception on the same antenna)
4		Transmitting and receiving radio station (alternative emission and reception on the same antenna)
5		Direction-finding radio station
6		Radio beacon station
7		Base radio station
8		Mobile radio station
9		Portable radio set
10		(One-way) radio-relay station Example. Receiving and transmitting at different frequencies f_1 and f_2
11		Passive relay station

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STUDY GROUP XIV

(Vocabulary)

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: Mr. R. VILLENEUVE (France)
Vice-Chairman: Mr. A. FERRARI-TONIOLO (Italy)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP XIV

1. Introduction

Whereas the activities of all the other C.C.I.R. Study Groups are similar in nature but differ in their fields of application, which are the various specialized branches of radio technique, the role of Study Group XIV is of a different kind and has a bearing on all the specialized branches indiscriminately.

The subjects within the terms of reference of the Study Group are the various categories of means of expression:

- terminology (vocabulary and definitions);
- graphical symbols;
- measurement units;
- letter symbols and other conventional signs (particularly mathematical);
- other related subjects (nomenclatures, classifications etc.).

All these subjects have one thing in common, namely, that the aim of studying them is to codify usage. This essential feature of the subject is reflected in the work on them, which demands at all times a high degree of coordination and cooperation at all levels.

In this work of codification, the conventions which suit the purposes of the C.C.I.R. Study Groups must not only form a consistent system, but must also agree, as closely as possible, with the conventions in use elsewhere, whether within the I.T.U. (the C.C.I.T.T. has a Study Group VII, the terms of reference of which closely resemble those of C.C.I.R. Study Group XIV) or outside it.

The terms of reference of the Study Group explicitly provide for cooperation within the I.T.U. As for a desire to cooperate with other organizations, this is constantly revealed in the texts it prepares and, in fact, a Resolution is specifically devoted to the question—Resolution 22 (Coordination of the work of the C.C.I.R. and of other organizations on unification of means of expression).

Among these organizations, special consideration is given to the International Electrotechnical Commission (I.E.C.), which has divided work on the various categories of means of expresison among four of its numerous technical committees: terminology (Technical Committee No. 1), graphical symbols (Technical Committee No. 3), electrical and magnetic quantities and units (Technical Committee No. 24), letter symbols and signs (Technical Committee No. 25).

2. Terminology

2.1 *Publication of a general list of terms and definitions for radio*

Resolution 21-1 outlines the preparations made for compiling this list from a basic document consisting of the final bilingual draft of the part of the International Electrotechnical Vocabulary (2nd edition) devoted to radio. Since the XIth Plenary Assembly, Technical Committee No. 1 of the I.E.C. held a meeting in London, November 1966, at which it recognized the draft submitted to it as the " definitive text " (subject to the correction of the numerous defects revealed during revision for the 3rd edition). Thus the basic document, long awaited by the C.C.I.R., will shortly be available.

2.2 *Action to keep the List up to date thereafter*

Within the framework of Resolution 22, the C.C.I.R., as also the C.C.I.T.T., accepted the invitation from Technical Committee No. 1 of the I.E.C. to be represented by observers at its meeting in November 1966, to consider the possibility of close cooperation, going as far as the constitution of Joint Study Groups. The minutes of the meeting contain a statement by the C.C.I.R., strongly favourable to the expedition of this work which has, hitherto, been proceeding extremely slowly. At the conclusion of these discussions, Technical Committee No. 1 proposed, in resolutions to the I.E.C. Action Committee, that it should aim at the compilation of a single telecommunication vocabulary, by cooperation in two stages: first, an agreement in principle by confirmation of the intentions of the organizations concerned, and then negotiations between their representatives to establish an appropriate organization.

2.3 *Specific points of terminology*

Annex I to Resolution 21-1 gives, in § 2, examples of solutions found for specific questions of terminology. These are presented either in the form of Recommendations, such as Recommendation 325 (Definition of the terms emission, transmission, and radiation), or as parts of Recommendations, such as § 1 of Recommendation 326 (Power of radio transmitters), or Annex II to Recommendation 342, on terms related to ARQ systems, or again in the form of Reports, such as Report 321 on clockwise or anti-clockwise elliptically or circularly polarized (electro-magnetic) waves. The recapitulatory list (given in the Table of Contents, page 11 of this Volume) of these various texts, indicates the section in which each has been placed. The Annex to Resolution 21-1, § 2.2, provides for the establishment of an International Working Party to consider terms and definitions relating to reliability. At its seventh and last meeting, the Study Group proposed (Doc. XIV/24, § 3.3), Dr. Kaiser (Federal Republic of Germany) as Chairman of this body.

3. Graphical symbols

The results obtained by the Joint Working Party, consisting of C.C.I.R. and C.C.I.T.T. representatives, and representatives of the I.E.C. (C.C.I.R. participation having been officially sanctioned by Resolution 23) are embodied in Report 335.

4. Units of measurement

Recommendation 430 advocates the adoption by the C.C.I.R. of the international MKS system, also known as the Giorgi system. Recommendation 431-1, § 1, advocates the adoption of the hertz (Hz) as the unit of frequency.

5. Letter symbols, conventional signs and miscellaneous

Recommendation 431-1, § 2, advocates the adoption of the " Nomenclature of the frequency and wave-length bands used in radiocommunication ", and Resolution 22, § 3, terminates the study of a Question on the possible use of the universal decimal classification by the C.C.I.R.

RESOLUTION 21-1

TERMS AND DEFINITIONS

The C.C.I.R., (1963 – 1966)

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, among the tasks to be accomplished in this respect, by far the most important and also the most difficult is establishing a definitive terminology; that the I.T.U. Administrative Council has recommended, in its Resolution 283, that as a first step a " List of definitions of essential telecommunication terms ", known hereafter as the " List ", should be compiled in English and in French. 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, since its VIth Plenary Assembly, the C.C.I.R. has consistently confirmed the imperative need for such work to be based on actual and efficient cooperation with any organization engaged on vocabulary matters in all or part of the same technical sphere, and above all with the International Electrotechnical Commission (I.E.C.), whose Committee I has been working for several years on a chapter in its " International Electrotechnical Vocabulary " devoted to radiocommunications, as a means of avoiding, unless imperatively necessary, real or apparent contradictions between the conventions respectively adopted;

(d) that the I.E.C., which has demonstrated a reciprocal willingness to cooperate, has now finished its bilingual draft and that, when submitting the draft to its national Committees " for approval according to the six months rule ", it also sent a considerable number of copies to the C.C.I.R. Secretariat, which undertook to distribute them as a basic document (Doc. XIV/1, Geneva, 1963), for the work on the vocabulary, as envisaged in the Annex to Resolution 62 (Los Angeles, 1959);

(e) that preliminary use of this basic document was made at the Xth Plenary Assembly by small " Joint Working Groups " set up (as suggested by the Chairman, Study Group XIV in his Report – Doc. 14, Geneva, 1963), from members of Study Group XIV and any of the other Study Groups, where at least one of the two " Specialized Collaborators ", requested by Study Group XIV (see Annex II), had been or was about to be appointed;

(f) that the preparation of the basic document was more difficult and would take more time than had been foreseen, but results can now be achieved, thanks to the cooperative effort, and that results would have to be used even if they were unofficial:

UNANIMOUSLY DECIDES

1. that the work already started will be continued by correspondence with all possible despatch, in accordance with the programme given in Annex I hereto, by an International Working Party under the guidance of the Chairman, Study Group XIV with the assistance of the Vice-Chairman;

2. that the members collaborating in this Working Group shall be:

– unless notified to the contrary by their respective Administrations, the " specialized collaborators " appointed respectively by:

Study Group I:	Mr. J. LOCHARD (France), Mr. D. E. WATT-CARTER (United Kingdom);
Study Group II:	Mr. C. MAREC (France), Mr. K. VREDENBREGT (Netherlands), and possibly Mr. R. LOWRY (United Kingdom);
Study Group III:	Mr. P. COUTENS (France), Mr. D. E. WATT-CARTER (United Kingdom);
Study Group IV:	Mr. M. THUÉ (France), Mr. S. M. MYERS (U.S.A.)
Study Group V:	Mr. L. BOITHIAS (France), Mr. F. HORNER (United Kingdom), and Mr. ...... (United States of America);
Study Group VI:	Mr. J. VOGE (France), Mr. P. A. MORRIS (United Kingdom);
Study Group VII:	Mr. B. DECAUX (France), Mr. J. M. STEELE (United Kingdom);
Study Group IX:	Mr. J. VERRÉE (France), Mr. ....
Study Group X:	Mr. S. LACHARNAY (France), Mr. G. JACOBS (United States of America), and possibly Mr. L. W. TURNER (United Kingdom);
Study Group XI:	Mr. L. GOUSSOT (France), Mr. ....
Study Group XIII:	Mr. J. BES (France), Mr. G. H. M. GLEADLE (United Kingdom);
Study Group CMTT:	Mr. L. GOUSSOT (France), Mr. ANDERSON (United Kingdom),

- each Study Group Chairman being responsible for appointing persons if necessary, for filling any gaps;
- a " National Collaborator " (see § 1.4 of Annex II) to be appointed by each of the following Administrations: United States of America, France, United Kingdom, Spain, U.S.S.R., Federal Republic of Germany and any other Administration deciding to do so, to supply the terms which have to be defined not only in English and French but also in other languages, and in particular in the other official languages of the I.T.U. The Administrations of Spain and U.S.S.R. have already announced that they will furnish a list of terms in Spanish and Russian in due course. National collaborators are asked to submit the lists of terms set out in this Resolution by 1 May 1967;

3. pending the final version of the I.E.C. document, a list of English and French terms should be prepared immediately, on the basis of the material collected by Study Group XIV, for consideration in preparation of the final version of the I.E.C. document; and for this purpose the various C.C.I.R. Study Groups are asked to study the list and indicate the terms which it should include later, in accordance with § 2 of Annex I;

4. the final objective shall be a publication as Part II of the I.T.U. List of definitions of essential telecommunication terms, giving the terms themselves in several languages, in accordance with the conclusions reached by the collaborators, the definitions being given in the official languages of the I.T.U.;

5. the preparatory lists drafted by the national collaborators will be bilingual or multilingual, one of the languages being either French or English; by some suitable device (cross-indexing or synoptical presentation) the terms will be associated with their synonyms; the exact concordance may be established later by the adoption of common definitions (some terms having perhaps to be amended for this purpose).

ANNEX I

Programme of work

Each member of the Working Party will find in Annex II, some general information on the broad outlines of the work and the division of duties.

If he has not already received one in Geneva, a copy of the basic document (Doc. XIV/1, Geneva, 1963), will be sent to him by the C.C.I.R. Secretariat, to the address he has given for mail relating to the Group's work by correspondence.

Each " Specialized Collaborator " for the various Study Groups will start by informing the Chairman or the C.C.I.R. Secretariat, as soon as possible, *on which sections of the document he intends to make a contribution:* some sections obviously apply to the terms of reference of specific Study Groups; others are of interest to several (or all) Study Groups; while others may not concern any of them.

1. Use of the I.E.C. draft

1.1 The first stage in the work has been partly covered in Geneva and could be very quickly finished. It consists of sorting into three categories, indicated by a letter *(a, b* or *c)*, opposite each French or English term and the corresponding definition in both French and English (i. e. four replies to be given for each serial number in the I.E.C. draft vocabulary), as follows:

(a) entirely satisfactory;

(b) provisionally acceptable for a first issue pending revision;

(c) unacceptable even provisionally, with the utmost tolerance; it would be preferable to leave a blank in the " List " until the requisite amendments have been found.

The most frequent defects observed will probably be *discrepancies* (serious or not), between the French and English definitions. This can be indicated by the letter *(d)*, between brackets: e. g., *b (d)*, will mean that the definition can be tolerated in spite of a discrepancy with the definition in the other language opposite it.

Lastly, a member replying to only a part of the terms in a section can mark the terms he has not dealt with by the letter *n* (" nil ").

The booklets, or parts of booklets (loose-leaf), with these annotations will be forwarded to the Chairman, or to the C.C.I.R. Secretariat, who will work together to obtain a coherent aggregate text.

This text will be forwarded to all the members of the Working Party and to the I.E.C. which should logically have the fullest possible information on the stages of the work. Administrations, which envisage subsequent translation of the List into other languages and wish to save time by beginning the translation of those parts which seem likely to be adopted, will also receive copies on request. It can also be forwarded to any of the Chairmen who so request.

1.2 The second stage of the work will be to draw up definitions and terms to replace the points in category *c*. Each member of the Working Party, to save time, is urged to start on the second stage as soon as he has finished and sent in his contribution to the first stage, without awaiting receipt of the aggregate text. Best of all would be for him to send in his proposed modifications for points in category *c* in successive batches.

The Chairman and the C.C.I.R. Secretariat will together collect these proposals and will also take account of any information they may get from the I.E.C. in its own review of the draft; they will endeavour to find satisfactory solutions for any difficulties that might arise.

As and when such solutions are obtained, they will be assembled and forwarded in batches to the various addresses listed in the last sub-paragraph of § 1.1.

1.3 Towards the end of the second stage of the work, the situation should have become sufficiently clear to be able to determine, by consultation with the members of the Working Party, what proposals should be made to Administrations as to the best use to be made of the results obtained. It might perhaps be wise to operate in two stages: to prepare first of all, by a cheap method (duplication), a comprehensive document suitable for temporary use, and only at a later stage to issue the final printed version, the details of which could be decided later.

2. Additional items to be studied on proposal of Study Groups or Administrations

2.1 *Terms of particular interest to a specific Study Group*

An example of this type is given by the proposal contained in Doc. 121, Geneva, 1963– Terms relating to ARQ systems. The study of this proposal was able to be made in Geneva, in a small " Joint Working Party ", set up by Study Groups III and XIV. The result was deemed sufficiently acceptable to be added as Annex VIII to Recommendation 342–1, but it was obtained in such a short time that a revision would appear necessary (particularly for the French text), before it can constitute a complement to the future " List ". This revision could be done, when time permits, by correspondence, within the framework of the activities of the Working Party, with the aid of the " specialized collaborators " of Study Group III.

2.2 *Terms concerning more than one specific Study Group*

An example of this type is given in Doc. 195 (U.S.S.R.), Geneva, 1963, which proposes terms to be used in the theory of reliability of radio systems. The proposal is of considerable interest. The addition of an Annex to the document, giving a translation of the Russian terms and definitions, was of great assistance in the assessment of the proposal. The French text only was distributed at the end of the third week of the Plenary Assembly.

As these terms, for the most part, touch upon far wider fields of application than merely those of radiocommunications, it would appear risky for the C.C.I.R. to approve the proposed vocabulary, without first receiving sufficient information on the various works on terminology at present being undertaken by the different organizations concerned with the theory of reliability in general.

Study Group XIV has therefore requested its Chairman to take up contact with these organizations, and thus to collect all useful data, before drawing up, with any help he may obtain by correspondence from members of the Working Party, a text which could become a complement to the " List ".

For this task, the Working Party might be augmented by national collaborators, appointed by those Administrations that could take an active part in it. To that end, in view of the delay in distributing the English text of the Addendum to Doc. 195, Geneva, 1963, the C.C.I.R. Secretariat is requested to consult the Administrations taking part in the work of Study Group XIV, in the same way as for Doc. XIV/1, by sending them Doc. 195, Geneva, 1963, its Addendum and this Resolution.

2.3 The same method of procedure could be applied to any other type of proposal, which might be submitted at any time to the Working Party, and which might give rise to complements to the future " List ".

ANNEX II

EXTRACT FROM THE ANNEX TO RESOLUTION 62 (Los Angeles, 1959)

. . . .

1.4 The other active collaborators of Study Group XIV, whose cooperation has been envisaged in principle, are those referred to in § 2 of Recommendation 144 as *National Correspondents*. In this case, too, the results have fallen short of expectations.

The Chairman, Study Group XIV earnestly requests the Administrations of each country, in which work on the vocabulary is being actively carried out and which can supply contributions in English or French, to designate by name a *National Collaborator* for Study Group XIV.

The help of such collaborators will be a decisive factor in the establishment of terms and definitions to be adopted by the C.C.I.R., whose vocabulary must be as close as possible to any vocabularies appearing in the countries of certain Member Administrations.

The cooperation must not, however, be limited to communicating to the Chairman, Study Group XIV the final result of the work whose slow and laborious nature is well known. In the interests of efficiency and speed, which are particularly desirable in such a rapidly expanding field as radiocommunication, drafts and other working documents should be available at the beginning of the work and at the successive stages.

. . . .

RESOLUTION 22 *

COORDINATION OF THE WORK OF THE C.C.I.R. AND OF 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 (I.E.C.);

(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);

* This Resolution replaces § 2 of Resolution 62.

UNANIMOUSLY RESOLVES

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, Study Group XIV 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 TELECOMMUNICATION

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 (I.E.C.), and that actual and efficient cooperation must be secured for this purpose;

(c) that the I.E.C., 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 I.E.C./I.T.U. Committee, with an equal number of I.T.U. (C.C.I.T.T. and C.C.I.R.) representatives and I.E.C. 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 I.E.C. 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 I.E.C. 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 RESOLVES

that the C.C.I.R. confirms its agreement to take part in the work of the Joint I.E.C./I.T.U. Committee, set up at the proposal of the I.E.C., 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, Study Group XIV informed of the progress of the work.

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LIST OF DOCUMENTS CONCERNING STUDY GROUP XIV
(Period 1963-1966)

Doc.	Origin	Title	Reference
XIV/1	C.C.I.R. Secretariat	Reproduction of Doc. 195 and Add. 1 (Geneva, 1963) and Doc. 2384 (Geneva, 1963)	
XIV/2	C.C.I.R. Secretariat	First series of lists of international graphical symbols for telecommunications proposed by the Joint C.C.I./I.E.C. Working Party	Res. 23
XIV/3 (IV/76) and Add. 1	France	Terms and definitions relating to space radiocommunication	Rep. 204
XIV/4	F. R. of Germany	General graphical symbols for use in the telecommunications field	Res. 23
XIV/5	C.C.I.R. Secretariat	Second series of lists of international graphycal symbols for telecommunications proposed by the Joint C.C.I./I.E.C. Working Party	Res. 23
XIV/6 (VI/239)	France	Draft revision of Report 204 – Terms and definitions relating to space radiocommunication	Rep. 204
XIV/7	Canada	Proposed method for resolving possible mis-interpretation of the term " effective radiated power "	Draft Rec., Res. 21
XIV/8	O.I.R.T.	Graphical symbols for telecommunications	Doc. XIV/2
XIV/9	C.C.I.R. Secretariat	General graphical symbols for telecommunications	Res. 23
XIV/10	Chairman, S.G. XIV	Report by the Chairman – Vocabulary	
XIV/11	Study Group XIV	Summary record of the first meeting	
XIV/12 (IV/262) and Corr. 1 and 2	Study Group IV	Draft Report – Terms and definitions relating to space radiocommunications	
XIV/13 (IV/263) (IX/259) and Corr. 1	Study Group IV	Draft Recommendation – Nomenclature concerning radiated power	
XIV/14	Study Group XIV	Summary record of the second meeting	
XIV/15 (IV/276) (IX/274) and Corr. 1 and 2	Terminology Working Party of S.G. IV	Draft letter from the Chairman, Study Group IV to the Chairman, Study Group XIV	
XIV/16	Study Group XIV	Summary record of the third meeting	
XIV/17 (IV/310)	Study Group IV	Report of the Terminology Working Group	
XIV/18	Study Group XIV	Draft Resolution	
XIV/19	Study Group XIV	Draft Resolution – Terms and definitions	
XIV/20	Working Group XIV-A	Draft Report – General graphical symbols for telecommunication	Res. 23

Doc.	Origin	Title	Reference
XIV/21	Study Group XIV	Summary record of the fourth meeting	
XIV/22	Study Group XIV	Summary record of the fifth meeting	
XIV/23	Study Group XIV	Summary record of the sixth meeting	
XIV/24	Study Group XIV	Summary record of the seventh meeting	
XIV/25	Study Group XIV	Status of texts	
XIV/26	C.C.I.R. Secretariat	List of documents issued (XIV/1 to XIV/26)	

LIST OF DOCUMENTS OF THE XIth PLENARY ASSEMBLY ESTABLISHED BY STUDY GROUP XIV

No.	Title	Final text
XIV/1001	Nomenclature of the frequency and wavelength bands used in radiocommunications	Rec. 431-1
XIV/1002	General graphical symbols for telecommunication	Rep. 355
XIV/1003	Terms and definitions	Res 21-1
XIV/1004	List of documents issued (XIV/1001 to XIV/1004)	