



This electronic version (PDF) was scanned by the International Telecommunication Union (ITU) Library & Archives Service from an original paper document in the ITU Library & Archives collections.

La présente version électronique (PDF) a été numérisée par le Service de la bibliothèque et des archives de l'Union internationale des télécommunications (UIT) à partir d'un document papier original des collections de ce service.

Esta versión electrónica (PDF) ha sido escaneada por el Servicio de Biblioteca y Archivos de la Unión Internacional de Telecomunicaciones (UIT) a partir de un documento impreso original de las colecciones del Servicio de Biblioteca y Archivos de la UIT.

(ITU) للاتصالات الدولي الاتحاد في والمحفوظات المكتبة قسم أجراه الضوئي بالمسح تصوير نتاج (PDF) الإلكترونية النسخة هذه والمحفوظات المكتبة قسم في المتوفرة الوثائق ضمن أصلية ورقية وثيقة من نقلًا.

此电子版（PDF版本）由国际电信联盟（ITU）图书馆和档案室利用存于该处的纸质文件扫描提供。

Настоящий электронный вариант (PDF) был подготовлен в библиотечно-архивной службе Международного союза электросвязи путем сканирования исходного документа в бумажной форме из библиотечно-архивной службы МСЭ.

INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

**C.C.I.R.**

DOCUMENTS OF THE  
**Xth PLENARY ASSEMBLY**

GENEVA, 1963

**VOLUME I**

EMISSION  
RECEPTION  
VOCABULARY



Published by the  
**INTERNATIONAL TELECOMMUNICATION UNION**  
GENEVA, 1963

INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

**C.C.I.R.**

DOCUMENTS OF THE  
**Xth PLENARY ASSEMBLY**

GENEVA, 1963

**VOLUME I**

EMISSION  
RECEPTION  
VOCABULARY



Published by the  
INTERNATIONAL TELECOMMUNICATION UNION  
GENEVA, 1963



**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

**EMISSION**

**Recommendations of Section A (Emission)**

**Reports of Section A (Emission)**

**Questions and Study Programmes attributed to Study Group I (Emission) – Opinions and Resolutions concerning Study Group I. – List of Documents of the Xth Plenary Assembly concerning Study Group I.**

**RECEPTION**

**Recommendations of Section B (Reception)**

**Reports of Section B (Reception)**

**Questions and Study Programmes attributed to Study Group II (Receivers) – Opinions and Resolutions concerning Study Group II. – List of Documents of the Xth Plenary Assembly concerning Study Group II.**

**VOCABULARY**

**Recommendations of Section K (Vocabulary)**

**Reports of Section K (Vocabulary)**

**Questions and Study Programmes attributed to Study Group XIV (Vocabulary) – Opinions and Resolutions concerning Study Group XIV. – List of Documents of the Xth Plenary Assembly concerning Study Group XIV.**

**DISTRIBUTION OF THE TEXTS OF THE Xth PLENARY ASSEMBLY  
OF THE C.C.I.R. AMONG VOLUMES I-VI**

**1. Recommendations**

Number	Volume	Number	Volume	Number	Volume
45	III	218, 219	III	289, 290	IV
48, 49	V	224	III	297-300	IV
75-77	III	237	I	302	IV
80	V	239	I	304-306	IV
100	III	240	III	310, 311	II
106	III	246	III	313	II
136	V	257, 258	III	314	IV
139, 140	V	259	IV	325-334	I
162	III	261, 262	V	335-349	III
166	III	264-266	V	350-367	IV
168	II	268	IV	368-373	II
182	III	270-271	IV	374-379	III
205	V	275, 276	IV	380-406	IV
212	V	279	IV	407-421	V
214-216	V	281-283	IV	422-429	III
				430, 431	I

**2. Reports**

Number	Volume	Number	Volume	Number	Volume
19	III	107	III	195-203	III
32	V	109	III	204-226	IV
42	III	111	III	227-266	II
43	II	112	III	267-282	III
46	II	122	V	283-290	IV
77	V	130	IV	291-316	V
79	V	134	IV	317-320	III
93	III	137	IV	321	I
106	III	151	II	322	*
		175-194	I		

**3. Resolutions**

Number	Volume	Number	Volume	Number	Volume
1	III	14-16	III	19, 20	III
2-13	II	17, 18	IV	21, 22	I
				23-29	VI

\* Published separately.

#### 4. Opinions

Number	Volume	Number	Volume	Number	Volume
1, 2 3	I IV	4-10 11	II III	12-14 15-19 20, 21	IV V III

#### 5. Questions

Number	Volume	Number	Volume	Number	Volume
3	III	163	III	221	IV
23	V	166	V	222	V
43	III	175-177	I	225	I
66	V	180-183	III	226	III
74	III	185	II	227-231	I
81	III	188	III	232, 233	III
95	III	191	III	234-245	IV
102	V	192-195	IV	246-248	II
118	V	197	IV	249-259	III
120, 121	V	199, 200	V	260, 261	IV
132, 133	III	205	V	262-270	V
140	III	206	III	271-275	III
152-154	V	207	I	276-279	IV
156, 157	V	219, 220	I	280-282	III

#### 6. Study Programmes \*

Number	Volume	Number	Volume	Number	Volume
36	V	127	I	176	II
57	II	139	II	177	V
102	III	148	II	180-185	I
110	V	153	II	186, 187	III
119	V	161, 162	V	188-206	II
		170	V	207	III

\* This list includes only those Study Programmes which do not derive from Questions. A Study Programme derived from a Question carries the same serial number as this Question, followed by a letter (e. g., S. P. 102A(XII)). It is inserted in the book immediately after the text of the Question from which it is derived.

**ARRANGEMENT OF VOLUMES I TO VII OF THE DOCUMENTS  
OF THE Xth PLENARY ASSEMBLY OF THE C.C.I.R.**

(Geneva, 1963)

- 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 C.M.T.T.).
- VOLUME VI** Resolutions of a general nature.  
Reports to the Plenary Assembly.  
List of participants.  
List of documents in numerical order.
- VOLUME VII** Minutes of the Plenary Meetings.

*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 Xth 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.

---

## TABLE OF CONTENTS OF VOLUME I

	Page
Distribution of the texts of the Xth Plenary Assembly of the C.C.I.R. among Volumes I to VI . . .	4
Arrangement of Volumes I to VII of the Xth Plenary Assembly of the C.C.I.R. . . . .	6
Table of contents of Volume I . . . . .	7

### RECOMMENDATIONS OF SECTION A (EMISSION)

Rec. 325	Definitions of the terms emission, transmission and radiation . . . . .	13
Rec. 326	Power of radio transmitters – Relationships between the peak envelope power, the mean power and the carrier power of a radio transmitter . . . . .	14
Rec. 327	Measurement of spectra and bandwidths of emissions . . . . .	28
Rec. 328	Spectra and bandwidths of emission . . . . .	33
Rec. 329	Spurious radiation (of a radio emission) . . . . .	40

### REPORTS OF SECTION A (EMISSION)

Report 175	Classification and designation of emissions . . . . .	47
Report 176	Compression of the radiotelephone signal spectrum in the HF bands . . . . .	63
Report 177	Compression of the radiotelegraph signal spectrum in the HF bands . . . . .	64
Report 178	Possibilities of reducing interference and of measuring actual traffic spectra . . . . .	65
Report 179	Bandwidth of telegraphic emissions A1 and F1. Evaluation of interference produced by these emissions . . . . .	78
Report 180	Frequency stabilization of transmitters . . . . .	88
Report 181	Frequency tolerance of transmitters . . . . .	90
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 . . . . .	93

### QUESTIONS AND STUDY PROGRAMMES ASSIGNED TO STUDY GROUP I (TRANSMITTERS); OPINIONS OF INTEREST TO THIS STUDY GROUP

Introduction by the Chairman, Study Group I . . . . .	95
Question 207(I) Classification of emissions . . . . .	97
Opinion 1 Classification and designation of emissions . . . . .	98

	Page
Question 219(I)    Compression of the radiotelephone signal spectrum in the HF bands . . . . .	98
Question 220(I)    Compression of the radiotelegraph signal spectrum in the HF bands . . . . .	99
Study Programme 180(I)    Methods of measuring emitted spectra in actual traffic . . . . .	100
Study Programme 181(I)    Spectra and bandwidth of emissions . . . . .	100
Study Programme 182(I)    Spurious radiation (of an emission) . . . . .	103
Study Programme 183(I)    Frequency stabilization of transmitters . . . . .	104
Study Programme 184(I)    Frequency tolerance of transmitters . . . . .	105
Question 227(I)    Limitation of radiation from industrial, scientific and medical installations and other kinds of electrical equipment . . . . .	106
Study Programme 227A(I)    Limitation of unwanted radiation from industrial installations . . . . .	107
Study Programme 227B(I)    Examination of results obtained by the International Special Committee on radio interference . . . . .	108
Study Programme 227C(I)    Protection of radiocommunication equipment from interference by industrial, scientific and medical installations and other kinds of electrical equipment . . . . .	109
Opinion 2            Cooperation with the International Special Committee on radio interference . . . . .	110
<b>List of documents of the Xth Plenary Assembly of the C.C.I.R. concerning Study Group I . . . . .</b>	<b>111</b>

The following texts, which are not contained in this Volume, also concern emission:

Text	Subject	Volume
Rec. 100	Radiotelephony transmitters . . . . .	III
Rec. 139	Transmitting antennae for tropical broadcasting . . . . .	V
Rec. 182	Monitoring of occupancy of the radio-frequency spectrum . . . . .	III
Rec. 205	Synchronized transmitters for HF broadcasting . . . . .	V
Rec. 214, 215	Power of transmitters for tropical broadcasting . . . . .	V
Rec. 266	Phase correction in television transmitters . . . . .	V
Rec. 347	Designation of channels in radiotelegraph systems . . . . .	III
Rec. 348	Channel arrangements in multi-channel radiotelephony systems . . . . .	III
Rec. 376	Frequency measurements at monitoring stations . . . . .	III
Rec. 426	Spurious emissions from maritime mobile equipment . . . . .	III
Rep. 301	Transmitting antennae for tropical broadcasting . . . . .	V

RECOMMENDATIONS OF SECTION B (RECEPTION)

	Page
Rec. 237	Sensitivity, selectivity and stability of amplitude-modulation and frequency-modulation sound-broadcast receivers . . . . . 115
Rec. 239	Spurious emissions from broadcast and television receivers . . . . . 115
Rec. 330	Sensitivity, selectivity and stability of television receivers . . . . . 116
Rec. 331	Noise and sensitivity of receivers . . . . . 117
Rec. 332	Selectivity of receivers . . . . . 136
Rec. 333	Tuning stability of receivers . . . . . 165
Rec. 334	Response of broadcast and television receivers to impulsive and quasi-impulsive interference. . . . . 174

REPORTS OF SECTION B (RECEPTION)

Report 183	Usable sensitivity of radio receivers in the presence of quasi-impulsive interference. . . . . 175
Report 184	Choice of intermediate frequency and protection against unwanted responses of superheterodyne receivers . . . . . 181
Report 185	Selectivity of receivers . . . . . 183
Report 186	Multiple-signal methods of measuring selectivity . . . . . 187
Report 187	Protection against interference between keyed signals . . . . . 188
Report 188	Criteria for receiver tuning . . . . . 193
Report 189	Methods of measuring phase/frequency or group-delay/frequency characteristics of receivers . . . . . 195
Report 190	Suppression of amplitude-modulation (caused by multipath propagation) in FM receivers . . . . . 197
Report 191	Tolerable receiver tuning instability . . . . . 199
Report 192	Tuning stability of receivers – Stability of intermediate-frequency amplifier with electro-mechanical filters, semi-conductor capacitors and ferromagnetic tuning . . . . . 201
Report 193	Spurious emissions from receivers . . . . . 202
Report 194	Interference caused to FM reception by AM and FM VHF mobile stations . . . . . 205

QUESTIONS AND STUDY PROGRAMMES ASSIGNED TO STUDY GROUP II (RECEIVERS);

Introduction by the Chairman, Study Group II . . . . .	207
Question 175(II) Usable sensitivity of radio receivers in the presence of quasi-impulsive interference. . . . .	210
Question 176(II) Spurious emissions from receivers excluding sound-broadcast and television . . . . .	211
Question 177(II) Distortion in frequency-modulation receivers due to multipath propagation . . . . .	211

	Page
Question 225(II) Diversity reception under conditions of multipath propagation . . . . .	212
Question 228(II) Sensitivity and noise factor . . . . .	213
Question 229(II) Selectivity of receivers . . . . .	214
Question 230(II) Tuning stability of receivers . . . . .	215
Question 231(II) Assessment of stability of a receiver . . . . .	216
Study Programme 127(II) Protection against keyed interfering signals . . . . .	216
Study Programme 185(II) Typical receivers . . . . .	218
<b>List of documents of the Xth Plenary Assembly of the C.C.I.R. concerning Study Group II . . . . .</b>	<b>234</b>

The following texts, which are not contained in this Volume, also concern receivers:

Text	Subject	Volume
Rec. 140	Receiving antennae for tropical broadcasting . . . . .	V
Rec. 338	Bandwidth required at the output of a receiver . . . . .	III
Rec. 411	HF broadcasting reception . . . . .	V
Rec. 415, 416	Specifications for low-cost broadcasting receivers . . . . .	V
Rec. 419	Directivity of receiving antennae . . . . .	V

RECOMMENDATIONS OF SECTION K (VOCABULARY)

Rec. 430	Unit systems . . . . .	237
Rec. 431	Nomenclature of the frequency and wavelength bands used in radiocommunications . . . . .	237

REPORT OF SECTION K (VOCABULARY)

Report 321	Terms and definitions . . . . .	239
------------	---------------------------------	-----

RESOLUTIONS CONCERNING STUDY GROUP XIV (VOCABULARY)

Resolution 21	Terms and definitions . . . . .	241
Resolution 22	Coordination of the work of C.C.I.R. and of other organizations on unification of means of expression . . . . .	245
Resolution 23	General graphical symbols for telecommunication . . . . .	246
<b>List of documents of the Xth Plenary Assembly of the C.C.I.R. concerning Study Group XIV . . . . .</b>		<b>247</b>

The following texts also concern the vocabulary:

Text	Subject	Volume
Rec. 166	Unity of quantity of information . . . . .	III
Rec. 310	Terms relating to the troposphere . . . . .	II
Rec. 325	Definitions of the terms emission, transmission and radiation . . . . .	I
Rec. 326	Definitions concerning power of transmitters . . . . .	I
Rec. 331	Definitions concerning sensitivity of receivers . . . . .	I
Rec. 332	Definitions concerning selectivity of receivers . . . . .	I
Rec. 341	Concept of transmission loss . . . . .	III
Rec. 342	Terms concerning ARQ systems . . . . .	III
Rec. 345	Telegraph distortion . . . . .	III
Rec. 369	Basic reference atmosphere . . . . .	II
Rec. 373	Meaning of “ MUF ” . . . . .	II
Rep. 204	Terms concerning space communications . . . . .	IV

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

RECOMMENDATIONS OF SECTION A: EMISSION

RECOMMENDATION 325

DEFINITIONS OF THE TERMS EMISSION, TRANSMISSION  
AND RADIATION

(Question 207(I), § 4)

The C.C.I.R.,

(Geneva, 1963)

CONSIDERING

- (a) that, Recommendation No. 8 (Question 207 (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. Énergie se propageant dans un milieu sous forme d'ondes radioélectriques.

*Émetteur (radioélectrique)*

Appareil produisant de l'énergie radioélectrique en vue d'assurer une radiocommunication.

*Ensemble émetteur (radioélectrique)*

Ensemble d'appareils comprenant un émetteur radioélectrique connecté à une ou plusieurs antennes ou plusieurs émetteurs connectés à une antenne commune.

*Emission (en radiocommunication)*

Rayonnement produit, ou production de rayonnement, à partir d'un ensemble émetteur radioélectrique.

*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.

*(Radio) Transmitter*

Apparatus producing radio-frequency energy for the purpose of radiocommunication.

*(Radio) Transmitting system*

Apparatus comprising a radio transmitter connected to its antenna or antennae; also several transmitters connected to a common antenna.

*Emission (in radiocommunication)*

Radiation produced, or the production of radiation, by a radio transmitting system.

*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 radioeléctricas.

*Transmisor (radioeléctrico)*

Aparato que genera energía radioeléctrica con objeto de asegurar una radiocomunicación.

*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.

*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.

*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.

*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.

*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.

*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 radioélectrico y la separación entre antenas no es mayor de unas pocas longitudes de ondas.

*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 radiocomunicación).

RECOMMENDATION 326 \*

**POWER OF RADIO TRANSMITTERS**

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

The C.C.I.R.,

(Geneva, 1951 – Los Angeles, 1959 – Geneva, 1963)

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 those 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 I 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:

\* This Recommendation replaces Recommendation 228.

- (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 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* (Radio Regulations, Geneva, 1959, Article 1, No. 97)

The average power supplied to the antenna transmission line by a transmitter during one radio-frequency cycle under conditions of no modulation. This definition does not apply to pulse-modulated emissions.

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:

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

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. Conversion factors between the different forms of power

In the following tables conversion factors are given, which can be used to obtain the power of a radio transmitter expressed in one of the forms defined above from the power given in another of those forms.

### 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 as unity.

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 signal modulation described in Column 3, and chosen so as to make that carrier power easily measurable.

TABLE I

Class of emission (1)	Applied modulating signal (2)	Condition of no signal modulation (3)	Conversion factor	
			Carrier power/ Peak envelope power (4)	Mean power/ Peak envelope power (5)
<i>Amplitude-modulation</i> <i>Double-sideband</i> 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 by the on-off keying of an emission frequency-modulated by a low frequency periodic oscillation	Series of rectangular dots; equal alternating marks and spaces; single sine-wave oscillation modulating the emission; no emission during space periods (Note 1)	Continuous emission	1	0.500 (-3.0 db) (Note 1)
A2 Telegraphy by on-off keying of one or more periodic oscillations low-frequency amplitude-modulating the emission, or by keying of the emission modulated by those oscillations (see Table II)	Series of rectangular dots; equal alternating marks and spaces; single sine-wave modulating the emission at 100% (a) modulating oscillation keyed  (b) modulated emission keyed (Note 1)	Continuous emission, modulating oscillation suppressed (carrier only) Continuous emission with modulating oscillation	0.250 (-6.0 db)  0.250 (-6.0 db)	0.312 (-5.1 db)  0.187 (-7.3 db) (Note 1)
A2 Continuous signal of an emission amplitude-modulated by low-frequency periodic oscillation (Example: some radio beacons)	Single sine-wave oscillation modulating emission to 100%; no keying	Continuous emission, modulating oscillation suppressed (carrier only)	0.250 (-6.0 db)	0.375 (-4.3 db)

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
A3 Double-sideband telephony, full carrier (See Table II)	(a) single sine-wave audio-frequency oscillation modulating emission 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)
<i>Amplitude-modulation</i> <i>Single-sideband</i> A2H Continuous signal of an emission amplitude-modulated by periodic oscillation, full carrier	Single sine-wave oscillation modulating emission 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 periodic sine-wave 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 periodic sine-wave oscillation modulating an emission 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)
A3J Single-sideband telephony, suppressed carrier	(a) two periodic amplitude sine-wave 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)

Class of emission (1)	Applied modulating signal (2)	Condition of no signal modulation (3)	Conversion factor	
			Carrier power/ Peak envelope power (4)	Mean power/ Peak envelope power (5)
<p><i>Amplitude-modulation Independent-sideband A3B</i></p> <p>Two independent telephony sidebands, carrier reduced or suppressed</p>	(a) single periodic sine-wave 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)
<p><i>Amplitude-modulation Facsimile A4</i></p> <p>Facsimile: direct modulation of the main carrier by the picture signal</p>	Black and white chequerboard picture giving square wave; modulating the carrier as for A1	Continuous emission	1	0.500 (-3.0 db)
<p>A4</p> <p>Facsimile: sub-carrier frequency-modulated by the picture signal, and amplitude-modulating the main carrier</p>	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)
<p>A4A</p> <p>Facsimile: sub-carrier frequency-modulated by the picture signal and amplitude modulating the main carrier, single sideband, reduced carrier</p>	For this class of emission, the modulation 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)

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
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
<i>Amplitude-modulation Television ASC</i> Television, vestigial sideband, picture only	(a) <i>All white</i> - 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) <i>All black</i> - 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)
<i>Multichannel Telegraphy A7A and A7B</i> (Note 5) Multichannel voice-frequency telegraphy. Single- or independent - sideband, reduced carrier	Frequency-shift or 2-tone voice-frequency channel telegraphy  2 channels    3 channels	Reduced carrier only	  0.025 (-16.0 db) 0.0025 (-26.0 db)  0.025 (-16.0 db) 0.0025 (-26.0 db)	  0.379 (-4.2 db) 0.454 (-3.4 db)  0.261 (-5.8 db) 0.302 (-5.2 db)

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
A7A and A7B (continued)	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  2 channels  3 channels  4 or more channels (Note 6)	Suppressed carrier	<0.0001 (<-40 db)	0.500 (-3.0 db)
A9B (Note 5) Combination of speech and multichannel telegraphy. 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)  Smoothly read text on two channels and one group of multichannel telegraph signals; 4 or more channels (Notes 6 and 7)	Reduced carrier only  Suppressed carrier  Reduced carrier only  Suppressed carrier	0.025 (-16.0 db) 0.0025 (-26.0 db)  <0.0001 (<-40 db)  0.025 (-16.0 db) 0.0025 (-26.0 db)  <0.0001 (<-40 db)	0.132 (-8.8 db) 0.138 (-8.6 db)  0.151 (-8.2 db)  0.105 (-9.8 db) 0.105 (-9.8 db)  0.113 (-9.5 db)
<i>Frequency or phase modulation</i> F1 F2 (frequency displacement on modulating oscillation) F3 F4 F5 F6 F9	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  1 1 1 1 1	1 1  1 1 1 1 1

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
<p><i>Pulse modulation</i> P0</p> <p>Continuous emission of a series of periodic pulses for radio-determination (See Note 8 for definition of <i>d</i>).</p> <p>Telegraphy by the on-off keying of a periodic oscillation which modulates a series of periodic pulses. (See Note 8 for the definition of <i>d</i>)</p>	<p>Periodic series of identical non-modulated pulses: amplitude, width (duration), repetition frequency of pulses is constant</p> <p>Series of rectangular dots; equal alternating marks and spaces; a single sine-wave oscillation modulating the pulses</p>	Without change	<i>d</i>	<i>d</i>
<p>P2D</p> <p>Periodic oscillation modulating the amplitude of the pulses</p>	<p>Amplitude of pulses modulated by sine-wave oscillation at 100%</p> <p>(a) modulating oscillation keyed</p>	Continuous series of periodic pulses, modulating oscillation suppressed	$0.250d$ (-6.0 + 10 log <i>d</i> ) db	$0.312d$ (-5.1 + 10 log <i>d</i> ) db
	<p>(b) modulated emission keyed (Note 1)</p>	Continuous series of pulses with modulating oscillation	$0.250d$ (-6.0 + 10 log <i>d</i> ) db	$0.187d$ (-7.3 + 10 log <i>d</i> ) db (Note 1)
<p>P2E</p> <p>Periodic oscillation modulating the width (duration) of pulses to constant mean width (duration)</p>	<p>(a) modulating oscillation keyed</p>	Continuous series of periodic pulses with modulating oscillation suppressed	<i>d</i>	<i>d</i>
	<p>(b) modulated emission keyed (Note 1)</p>	Continuous series of pulses with modulating oscillation	<i>d</i>	$0.500d$ (-3.0 + 10 log <i>d</i> ) db (Note 1)
<p>P2F</p> <p>Periodic oscillation modulating the phase or position of the pulses to constant mean spacing</p>	<p>(a) modulating oscillation keyed</p>	Continuous series of periodic pulses with modulating oscillation suppressed	<i>d</i>	<i>d</i>
	<p>(b) modulated emission keyed</p>	Continuous series of pulses with modulating oscillation	<i>d</i>	$0.500d$ (-3.0 + 10 log <i>d</i> ) db

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
<i>Pulse modulation</i> <i>Telephony</i> P3D Pulses amplitude-modulated by telephone signal	(a) single sine-wave oscillation modulating pulses at 100%	Periodic series of non-modulated pulses	$0.250d$ (-6.0 + 10 log $d$ ) db	$0.375d$ (-4.3 + 10 log $d$ ) db
	(b) smoothly read text	Periodic series of non-modulated pulses	$0.250d$ (-6.0 + 10 log $d$ ) db	$0.262d$ (-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				

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

TABLE II

Class of emission  (1)	Applied modulating signal  (2)	Condition of no signal modulation  (3)	Conversion factor	
			Carrier power/ Peak envelope power  (4)	Mean power/ Peak envelope power  (5)
A2 Telegraphy with on-off keying of one or more periodic oscillations amplitude-modulating the emission, or with keying of the emission modulated by those oscillations	Series of rectangular dots; equal alternating marks and spaces; single sinusoidal oscillation modulating the emission at 100% (a) modulating oscillation keyed	Continuous emission, modulating oscillation suppressed (carrier only)	4 (+6.0 db)	1.25 (+1.0 db)
	(b) modulated emission 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 sinewave audio-frequency sinusoidal oscillation modulating emission 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 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:  $0.5/0.5 = 1$ .

*Note 2.* — For smoothly read text, it is assumed that the mean power level of the speech signal is 10 db lower than the level of a reference sinusoidal oscillation. (This does not apply to broadcast emissions).

For A3 and A3H emissions, the reference oscillation drives the transmitter to 100% modulation.

For A3A and A3J single channel emissions, the reference oscillation drives the transmitter to peak envelope power.

For A3B emissions and for A3A and A3J multi-channel emissions, two sinusoidal oscillations of equal amplitude, each of reference level, applied simultaneously drive the transmitter to peak envelope power.

Although these practices do not correspond in all cases with those adopted by some Administrations, they result in practical average values in Column 5.

*Note 3.* — For independent-sideband emissions (A3B), of up to 4 channels, it is assumed that a different modulating signal is applied to each channel.

*Note 4.* – The condition of no signal 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.

*Note 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 a normal speech channel or channels.

*Note 6.* – When more than four telegraph channels are used, it is the normal practice to increase the power in each channel above that for which the total peak power allocated to the group of channels would never be exceeded. The mean power of the emission may thus be increased without exceeding the total admissible peak envelope power for more than a specified small fraction of the time. The ratios given in the table are typical of present practice in which the channel power is determined on the basis of voltage additions for the first four channels and power additions for the remainder. Thus, if  $n$  is the number of channels of identical peak power, the admissible peak power of each channel is given by:

$$\frac{\text{Total admissible peak power}}{n^2} \quad \text{when } n = 2 \text{ or } 3$$

$$\frac{\text{Total admissible peak power}}{4n} \quad \text{when } n \geq 4$$

The total peak power is not exceeded for more than about 1% to 2% of the time when  $n$  is greater than 4.

*Note 7.* – For composite emissions, the mean levels in speech channels are normally adjusted to the values as set out in Note 2 for A3B. To avoid interference from the group of telegraph channels, the level of this group is reduced, relative to the level as set out in Note 6, by 3 db when one channel is used for speech and by 6 db when more than one channel is so used.

*Note 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. Measurement of peak envelope power

That the determination and measurement of the useful peak envelope power of a radio transmitter should be made on the basis of the following considerations and methods.

#### 3.1 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 true 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 useful modulation depth to less than 100%.

The useful peak envelope power is limited by the acceptable intermodulation distortion. The method recommended for defining and measuring the useful 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).

### 3.2 Intermodulation

#### 3.2.1 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  $F_o + f_1$  and  $F_o + f_2$  (or  $F_o - f_1$  and  $F_o - f_2$ ).

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.

#### 3.2.2 Choice of frequencies for modulating oscillations

To measure the amplitude of the intermodulation products, it is desirable to use modulating oscillations whose frequencies are 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, not to a single telephone channel but to the whole of a sideband of the emission, at least when the transmitter provides several channels on a single sideband.

Moreover, to separate the intermodulation products from the harmonics of the modulating oscillations at the output of the transmitter, the frequencies of these oscillations should be chosen in such a way that they are not in harmonic relation. In practice, frequencies, the ratio of which is in the neighbourhood of one integer and a half will be chosen. For an audio-frequency passband between 300 c/s and 3 kc/s, for example, a value in the neighbourhood of 700 or 1100 c/s will be chosen for  $f_1$ , and in the neighbourhood of 1700 or 2500 c/s for  $f_2$ .

#### 3.2.3 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 (§ 3.2.1, 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 transmitter can be considered:

*First category*

Single channel radiotelephone emissions without a privacy device:

- single-sideband (A3A, A3J, A3H).

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, 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 useful peak envelope power of double-sideband transmitters may also be measured by means of the method recommended in § 3.3. This is mainly of use in determining the out-of-band radiation characteristics of 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%.

### 3.3 *Methods for measuring the peak envelope power*

It results from the foregoing that, because of non-linearity in the transmitters, the measurement of the useful 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 :

#### 3.3.1 *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 useful 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 § 3.2.2. 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 § 3.2.3) and that simultaneously the two oscillations produce fundamental components of equal amplitude at the output of the transmitter (§ 3.2.1).

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:

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

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

A measuring method similar to that described in § 3.3.1 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:

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

## RECOMMENDATION 327 \*

### MEASUREMENT OF SPECTRA AND BANDWIDTHS OF EMISSIONS

The C.C.I.R., (Geneva, 1951 – London, 1953 – Los Angeles, 1959 – Geneva, 1963)

#### 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;

\* This Recommendation replaces Recommendation 229.

## 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) of 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) of 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) of London, 1953)

The third method consists in dividing the occupied band into narrow bands of, say, 100 c/s, 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* (Doc. I/11 (Japan) of Geneva, 1962)

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).

Advantage may then be taken of the fact that, in most cases, the slope of spectra, in decibels per octave, tends to become constant, for frequencies distant enough from the central part of the spectrum. This slope can be determined by taking some measurements at a sufficiently high level to avoid disturbance by noise or interference. The bandwidth is determined by calculation, the slope of the spectrum being assumed to be constant after this has been checked by an adequate number of measurements.

## 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  $\pm 1\%$  in the measurement of the amplitude is obtainable, but an accuracy of  $\pm 5\%$  is sufficient for most practical purposes.

#### 2.1.1.2 Automatic sweep apparatus

Provided the speed of 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  $\pm 2$  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 telegraph speed.

#### 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  $\pm 0.1\%$ , 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  $\pm 1\%$  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  $\pm 2$  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 telegraph speed, seem to be fairly consistent with the results of measurements carried out with periodic signals (see Doc. I/7 (Federal Republic of Germany) of 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 telegraph speed.

## ANNEX I

### CHARACTERISTICS OF MEASURING EQUIPMENT WITH AUTOMATIC FREQUENCY-SWEEP

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

#### 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 c/s. 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 cycles per second, should not exceed the square of the filter bandwidth at the  $-3$  db points, expressed in cycles per second.

#### 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 kc/s should normally be adequate. For investigating narrow-band emissions, the range should be adjustable down to 1 kc/s.

#### 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 ANALYZERS PRESENTED BEFORE THE C.C.I.R. VIII<sup>TH</sup> PLENARY ASSEMBLY

Administration	Doc. No.	Exploration			Filter				Amplitude range (db)	Measuring instrument		Measurement of the component frequency
		Type	Sweep duration	Frequency band explored(kc/s)	Type	Bandwidth		Frequency (kc/s)		Observations	Recording	
						at -3 db	at other level					
Japan	127	automatic	1 min 5 min	6 and 20	crystal		50 c/s 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 c/s		40	0-20 20-40 40-60	oscillo- scope	recorder	
United Kingdom	168 ( <sup>1</sup> )	automatic	0.1; 0.3; 1; 3; 10; 30 s	0 to 30	crystal	6 c/s 30 c/s 150 c/s		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 c/s at -43.5 db	3		oscilloscope or peak voltmeter	photo- graphic	marks each 1 kc/s
Italcable	199	manual			LF		50 c/s at -80 db	1	calibrated attenuator	voltmeter		frequency- meter
France	349	automatic	6 and 36 s	2 and 6	crystal		6 or 30 c/s below 80 db	70	60	oscillo- scope	photo- graphic	
Belgium	( <sup>2</sup> )	automatic	6; 20; 45 s	0.5 to 30	crystal	9 c/s		195	20 db linear scale 60 db loga- rithmic scale	oscillo- scope	photo- graphic	marks 0.5 or 1 kc/s

(<sup>1</sup>) This apparatus has been demonstrated before Study Group I.

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

RECOMMENDATION 328 \*

SPECTRA AND BANDWIDTHS OF EMISSIONS

(Study Programme 181(I))

(Stockholm, 1948 – Geneva, 1951 – London, 1953 – Warsaw, 1956 –

The C.C.I.R.,

Los Angeles, 1959 – Geneva, 1963)

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;

---

\* This Recommendation replaces Recommendation 230.

- (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 outside 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.

2.0.1 The telegraph speed 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 A1 emissions 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 telegraph speed 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 telegraph speed.

This relative level of  $-3$  db corresponds to an absolute level of 27 db below the level of a continuous mark.

#### 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  $1/(5B)$ .

## 2.2 *Class A1 emissions, 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 telegraph speed in bauds.

## 2.3 *Class A2 emissions*

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 twice the keying frequency ( $F > B$ ), 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 telegraph speed in bauds, the envelope of the spectrum should lie below a curve starting at the points  $[\pm (f + 5B/2), -24 \text{ db}]$  with a slope of 12 db per octave, and extending over at least one octave, that is, out to the points  $[\pm (f + 5B), -36 \text{ db}]$ . Beyond these points the level of all the components emitted should be below  $-36 \text{ db}$ .

The reference level is the carrier level during a steady dash.

## 2.4 *Class A3 emissions*

The limitations given below for radiotelephone emissions have been deduced from measurements made by different methods. In one of these methods, two pure audio-frequency tones of equal amplitude are applied simultaneously at the input to the transmitter and the amplitude of intermodulation products outside the necessary band is measured at the output of the transmitter. In other methods, the voltage from a recording of conversational speech, or a white noise voltage, is substituted for the two audio-frequency tones.

These fundamentally different methods do not lead to the same result; however, the known results of measurements are within the limiting spectra specified below.

In the curves defined in §§ 2.4.1 and 2.4.2, the ordinates represent the energy intercepted by a receiver of a bandwidth practically equal to 3 kc/s, the central frequency of which is tuned to the frequency plotted on the abscissa, as compared with the energy which is intercepted by the same receiver, if it were tuned to the central frequency of the occupied band.

To make the corresponding measurements, the transmitter is considered to be supplying its useful peak envelope power, determined in accordance with Recommendation 326. The operating conditions, other than those which are imposed by the carrying out of the measurements, are assumed to correspond to normal conditions.

The comment contained in the last sentence of the definition of the occupied bandwidth (§ 1.1), can be applied to emissions of this class. A percentage of power, slightly lower than 0.5%, would probably give necessary and occupied bandwidth figures near to the currently accepted figures for necessary bandwidth, as defined by a spectrum component level criterion.

### 2.4.1 *Class A3 emissions, double-sideband*

#### 2.4.1.1 *Necessary bandwidth*

The necessary bandwidth 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*

To estimate the distribution of power within the necessary band statistically, when no privacy equipment is connected to the transmitter, the distribution shown by the C.C.I.T.T. for the "commercial circuit psophometer" can be used (Vol. V, Recommendation P53-A); in addition, the relative power

level of the different speech frequencies should be taken into account. 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 along the abscissae in logarithmic units and amplitude is plotted along the ordinates in decibels, the curve representing the out-of-band spectrum should lie below two straight lines starting from the points  $(\pm M, 0 \text{ db})$ , to the points  $(\pm 1.4 M, -20 \text{ db})$ . Beyond these points, and down to the level of  $-60 \text{ db}$ , this curve should lie below two straight lines starting from the latter points and having a slope of  $12 \text{ db per octave}$ . Thereafter, the same curve should lie below the level  $-60 \text{ db}$ .

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

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

#### 2.4.2.1 *Necessary bandwidth*

2.4.2.1.1 For A3A and A3H emissions, 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 A3J emissions, 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 A3B emissions, 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*

The power within the necessary band is determined as for class A3 double-sideband emissions (see § 2.4.1.2), considering each sideband separately, then each channel, and finally the level of the carrier, the limits of which are specified in §§ 2.4.2.1.1 and 2.4.2.1.2.

#### 2.4.2.3 *Out-of-band spectrum (for four telephone channels)*

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 along the abscissae in logarithmic units, the reference frequency being supposed to coincide with the centre of the necessary band, and if the power of the spectral components are plotted as ordinates, in decibels, the curve representing the out-of-band spectrum should lie below two straight lines starting at point  $(+0.5F, 0 \text{ db})$ , or at point  $(-0.5F, 0 \text{ db})$ , and finishing at point  $(+0.7F, -30 \text{ db})$  or  $(-0.7F, -30 \text{ db})$ , respectively. Beyond the latter points and down to the level  $-60 \text{ db}$ , 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 were distributed uniformly over the necessary bandwidth.

## 2.5 Class F1 emissions

For Class F1, frequency-shift telegraphy, with or without fading fluctuations:

### 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  $m$ :

$$2.6 D + 0.55 B \text{ within } 10\% \text{ for } 1.5 < m < 5.5,$$

$$2.1 D + 1.9 B \text{ within } 2\% \text{ for } 5.5 \leq m \leq 20.$$

### 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 amplitude of the unmodulated carrier. 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)
$1.5 \leq m < 6$	$-15$	$13 + 1.8 m$
$6 \leq m < 8$	$-18$	$19 + 0.8 m$
$8 \leq m \leq 20$	$-20$	$19 + 0.8 m$

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  $1/(12 B)$ , 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:

$$2.6 D + 1.4 B \text{ within } 2\% \text{ for } 2 \leq m \leq 8,$$

$$2.2 D + 3.1 B \text{ within } 2\% \text{ for } 8 \leq m \leq 20.$$

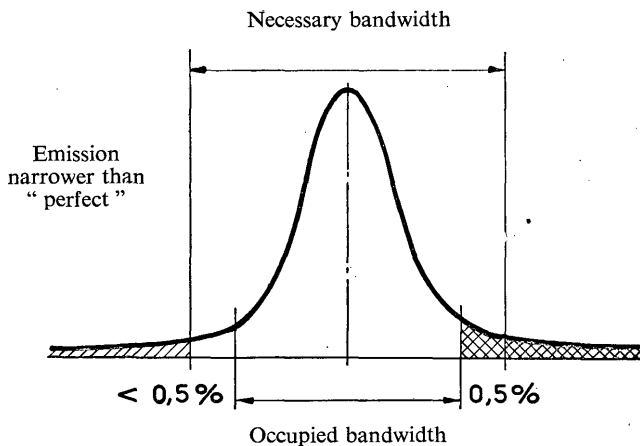
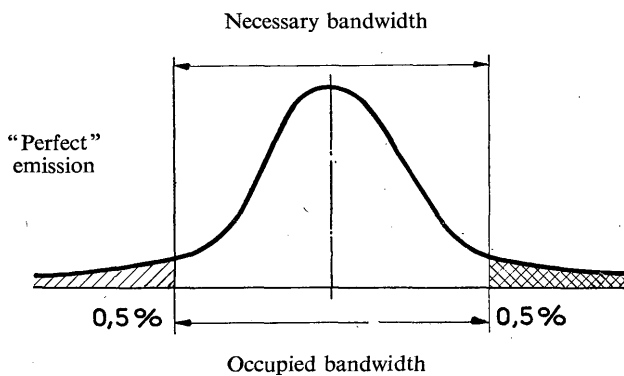
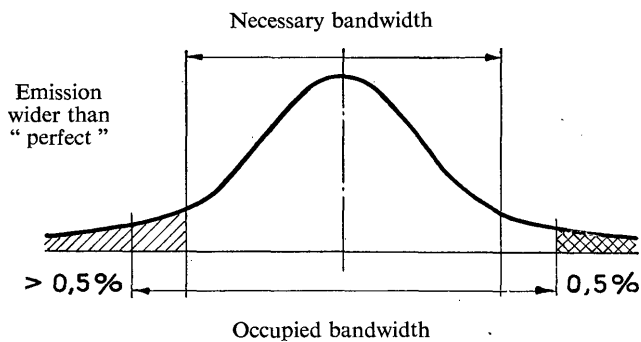
ANNEX

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)

RECOMMENDATION 329 \*  
SPURIOUS RADIATION (OF A RADIO EMISSION)

(Study Programme 182(I))

The C.C.I.R.,

(Geneva, 1951 – London, 1953 – Warsaw, 1956 –  
Los Angeles, 1959 – Geneva, 1963)

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 Mc/s in terms of power supplied to the antenna on the frequency, or frequencies, of each spurious emission;
- (b) that Article 12, § 4 (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, 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 what are regarded as spurious radiations;

---

\* This Recommendation replaces Recommendation 232.

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 stations; 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 performances in § 3 below are adopted by an Administrative Radio Conference as revised limits for Appendix 4 of 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.

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 kc/s and 30 000 kc/s (from Radio Regulations, Geneva, 1959, Appendix 4, Table, Column B);  
for any spurious radiation, the mean power supplied to the antenna should be at least 40 db below the power of the fundamental emission, without exceeding the value of 50 mW (see Notes 3, 4 and 5);
- 3.2 that the following limits are realizable with new transmitters having fundamental frequencies between 30 Mc/s and 235 Mc/s (see Radio Regulations, Geneva, 1959, Appendix 4, Table, Column B);

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

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

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

For any spurious radiation, the mean power supplied to the antenna should be at least 40 db below the power of the fundamental emission, without exceeding the value of 25  $\mu$ W;

3.3 that the following limits are realizable for new transmitters with fundamental frequencies between 235 Mc/s and 960 Mc/s;

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

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

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

It is not yet possible to specify limits for transmitters in this category, due to lack of sufficient data;

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 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 equipments 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, 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 the same station comprises several transmitters feeding 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 radiodetermination stations, until acceptable methods of measurement exist, the lowest practicable level of spurious radiation should be achieved.

*Note 9.* – For survival stations, operating on a frequency of 243 Mc/s, 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;

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

#### 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, so 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.* 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.
- 4.2.2 *Second method* \*. 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.

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.

The power transferred by each conductor of a feeder system may be measured separately.

- 4.2.3 *Third method* \*\*. 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

\* See Doc. I/1 of Geneva, 1962.

\*\* See Doc. I/23 of Geneva, 1962.

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* \*

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 insure that the limitations set forth in § 3 are met in such cases (see Study Programme 182 (I), § 2).

4.3.2 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 Mc/s 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 deduced by calculation from the result of these measurements. 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 provided for in § 3, for example, by:

- the use of low-pass or other output filters;
- suitable coupling circuits;
- screening of various stages in transmitters, filters and other parts of the equipment, which otherwise might emit spurious radiations directly or by coupling.

### 6. Radioastronomy

radioastronomy uses extremely sensitive receivers, and will probably need special protection. The C.C.I.R. is unable to proceed with the study of this problem until an answer to Question 244 (IV) has been provided.

### 7. Space service

another special case requiring urgent study is that of 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.

---

\* See Doc. I/17 of Geneva, 1962

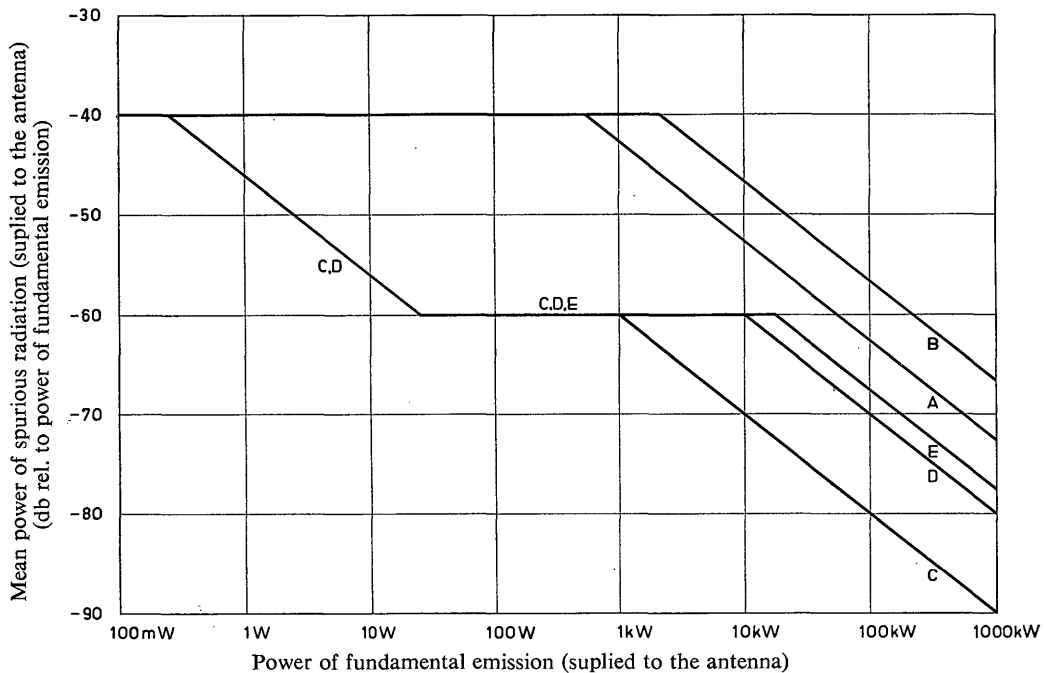


FIGURE 1

- Curve A :  $10 \text{ kc/s} < F < 30 \text{ Mc/s}$
  - Curve B :  $10 \text{ kc/s} < F < 30 \text{ Mc/s}$  (Notes 3 and 5)
  - Curve C :  $30 \text{ Mc/s} < F < 235 \text{ Mc/s}$
  - Curve D :  $30 \text{ Mc/s} < F < 235 \text{ Mc/s}$  (Note 6)
  - Curve E :  $235 \text{ Mc/s} < F < 960 \text{ Mc/s}$
- ( $F$  = fundamental frequency)

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

REPORTS OF SECTION A: EMISSION

REPORT 175 \*

CLASSIFICATION AND DESIGNATION OF EMISSIONS

(Question 207(I))

(Geneva, 1963)

**1. Introduction**

This Report reviews certain aspects of the problem and presents a proposal for a new method of classifying and symbolizing emissions, taking into account those features of the contribution and comments, submitted by Administrations, which the I.F.R.B. considers to be best suited for the elaboration of a new method.

**2. Aspects to be considered in evolving a new method of symbolization for designation emissions**

2.1 The object of describing different emissions by appropriate symbols is to give the user, in a summarized form, an adequate knowledge of:

- the characteristics of the modulations and multiplexing,
- the type of modulating signal conveying the information.

2.2 A description of the preliminary processing or coding of the information, or of the intermediate steps involved in the transfer of intelligence from the input of the electrical operations to the radio wave is important, only insofar as such a description is useful in helping to identify the type of information transmitted, or in enabling spectrum occupancy and power distribution to be derived from the main features of the radiated wave.

2.3 The convenience of a method of designating and classifying emissions in symbolic form is obvious, and the application of such a method has become a special coded language, expanded from time to time to provide for new developments in transmission techniques. The existing method of symbolisation, however, cannot describe certain important features, which are considered essential if the two conditions mentioned in § 2.1 are to be fulfilled; and it has become necessary to counteract this lack of flexibility by providing supplementary explanations in plain language.

2.4 To facilitate handling of the data by an electronic or mechanical process, an essential prerequisite for a modern system, the method of symbolization should give the same number of code characters for any emission. Thus, according to such a system, in the symbol group designating any emission, the position of any individual character within the group would immediately indicate what aspect of the emission it described. At the same time, the number of character-symbols necessary to define any emission should be as small as possible.

The present proposal is a 5-character system, comprising 3 digits and 2 letters.

2.5 Before any attempt could be made to devise a new method of symbolization, which would describe all important aspects of an emission, an analysis had to be made of all the different

---

\* This Report was adopted unanimously.

components or features of the emission. In this connection, the characteristics listed in Annexes I and II to this Report were a useful guide in determining which of these characteristics or features had to be included.

2.6 The result of this analysis, based on available information, has led to the formulation of the following considerations:

2.6.1 The use of one character-symbol to describe only the type of modulation of the main carrier, while it has mnemonic advantages, prevents the use of a number of characters and lengthens the total description, in character-symbols, of an emission with a more complex modulation. It would be more economical to use a letter (A to Z), as a character-symbol describing all possible characteristics of the modulations and multiplexing, rather than to allocate one character-symbol for the sole purpose of describing the main type of modulation.

2.6.2 On the other hand, the strict concept of modulation, in the sense that it is a means employed to vary the radio wave by a modulating signal for the transmission of information, has become more difficult to describe, in particular in those cases where an oscillation modulating a carrier wave does not itself convey intelligence. The modulating signal conveying the information may or may not directly modulate the main carrier; different processes of modulation can be used for a particular type of modulating signal; also, different types of modulating signal can be applied to the radio wave with a particular form of modulation.

2.6.3 The description of the modulating signal used to convey information should cover all necessary characteristics which are used, or could be used. Instead of using a numerical character-symbol of one digit number (0 to 9) to describe a "type of transmission" as such, it would be more effective to use a character-symbol consisting of a letter (A to Z) to differentiate, for the same "type of transmission", those types of modulating signal which have different characteristics and consequently may have an influence on the occupied bandwidth and power distribution, as well as on vulnerability to interference.

2.7 In describing the characteristics of the modulations and multiplexing, it is convenient to make two main distinctions between:

- a continuous carrier wave;
- a pulsed carrier wave.

2.7.1 Distinction should also be made between the following types of continuous-wave carriers: full and reduced or suppressed carrier; between double-sidebands, single-sideband, and independent-sidebands; between amplitude-modulation, frequency-modulation and frequency-shift of the carrier; between single channel systems and multi-channels in frequency-division multiplex systems with constant frequency arrangements of channels or sub-carriers, etc.

2.7.2 Pulsed carriers should also be further subdivided, in accordance with the modulation of the pulses by the modulating signal, and a distinction should be made between amplitude, width (duration) and phase (position).

2.8 In the description of the modulating signal, the classification should be based on the characteristics of the signal which convey the information.

### 3. Proposed method of designation of emissions

3.1 It is proposed that the designation of emissions should consist of the following:

3.1.1 A symbol consisting of a three-digit number, indicating the necessary bandwidth;

3.1.2 A symbol consisting of a single letter, indicating the characteristics of the modulations and multiplexing;

3.1.3 A symbol consisting of a single letter, indicating the characteristics of the modulating signal.

3.2 *Bandwidth indicator*

The necessary bandwidth should be symbolized by three numerical digits as follows:

The first two digits are the first two significant figures of the necessary bandwidth expressed in c/s, the third is the power of 10 by which the first two figures must be multiplied to produce the necessary bandwidth expressed in c/s. For example, necessary bandwidths of 25 c/s, 400 c/s, 36 kc/s, 180 kc/s, 6.25 Mc/s, 200 Mc/s, and 5.6 Gc/s, are expressed by the respective bandwidth indicator 250, 401, 363, 184, 625, 207 and 568 instead of 0.025, 0.4, 36, 180, 6250, 200 000 and 5 600 000 as at present.

3.3 *Indicator of the characteristics of the modulations and multiplexing*

The characteristics of modulations and multiplexing should be classified and symbolized in accordance with the indications in Table I.

3.4 *Indicator of the characteristics of the modulating signal*

The modulating signal should be classified and symbolized in accordance with the indications in Table II.

4. Table III shows examples of emissions, with comparisons between symbolization with the present method and the proposed new method.

TABLE I

*Characteristics of the modulations and multiplexing*

Description	Symbol
Continuous-wave carrier, non-keyed, non-modulated; or on-off keyed by the modulating signal; absence of any other modulation; single channel, may be sub-channelled in time division . . . . .	A
Full continuous-wave carrier, modulated in amplitude or frequency by one or more periodic oscillation; the oscillation is on-off keyed by the modulating signal or the modulated emission is on-off keyed by the modulating signal; single channel, may be sub-channelled in time division . . . . .	B
Full continuous-wave carrier, amplitude-modulated, double-sideband: Single channel, may be sub-channelled in time division. . . . . Multi-channels; frequency-division multiplex with constant frequency arrangements of channels; each channel may be sub-channelled in time division . . . . .	C D
Full continuous-wave carrier, amplitude-modulated, single-sideband or vestigial sideband: Single channel, may be sub-channelled in time division. . . . . Multi-channels; frequency-division multiplex with constant frequency arrangements of channels; each channel may be sub-channelled in time division . . . . .	E F
Reduced or suppressed continuous-wave carrier, amplitude-modulated, single-sideband or vestigial-sideband: Single channel, may be sub-channelled in time division (Note 1). . . . .	G

Description	Symbol
Multi-channels; frequency-division multiplex with constant frequency arrangements of channels; each channel may be sub-channelled in time division . . . . .	H
Reduced or suppressed continuous-wave carrier, amplitude-modulated, two independent-sidebands:	
Single channel in each sideband; each channel may be sub-channelled in time division	I
Multi-channels; frequency-division multiplex with constant frequency arrangements of channels in each sideband; each channel may be sub-channelled in time division . . . . .	J
	K
	L
	M
	N
	O
Pulsed carrier, non-keyed, non-modulated; or pulsed carrier on-off keyed by the modulating signal, absence of any other modulation . . . . .	P
Pulsed carrier, pulses amplitude-modulated by the modulating signal . . . . .	Q
Pulsed carrier, pulses width (or duration) modulated by the modulating signal . . . . .	R
Pulsed carrier, pulses phase (or position) modulated by the modulating signal. . . . .	S
	T
Frequency or phase modulated carrier, except frequency-division multiplex telegraphy . . . . .	U
Frequency-division multiplex telegraphy, in which information is conveyed by a variable frequency arrangement of significant conditions, emitting one condition at a time . . . . .	V

Description	Symbol
	W
	X
Carrier modulated by processes not described above. . . . .	Y
Carrier modulated simultaneously by two or more of the foregoing processes; modulation used for identification only being ignored . . . . .	Z

TABLE II  
*Characteristics of the modulating signal conveying the information*

Description	Symbol
Absence of modulating signal. . . . .	A
Constant periodic oscillation or oscillations . . . . .	B
A discrete number of significant conditions (usually two) per channel with signal elements of pre-determined duration (alphanumeric telegraphy, data transmission, time signals, telemetry, remote control and some navigational beacons):	
For aural reception, up to 20 bauds. . . . .	C
For automatic reception up to 100 bauds aggregate speed . . . . .	D
For automatic reception up to 100 bauds aggregate speed but with automatic repetition	E
For automatic reception above 100 bauds aggregate speed . . . . .	F
For automatic reception above 100 bauds aggregate speed but with automatic repetition	G
	H
	I
	J
	K

Description	Symbol
	L
	M
A discrete number of significant conditions (usually two) per channel with signal elements of continuously variable duration, the information being conveyed by the time of transition from one significant condition to another (two condition facsimile, data transmission systems, etc.). . . . .	N
Continuously variable modulating signal (half-tone facsimile and analogue-data transmission)	O
Telephony using analogue techniques (including sound broadcasting and the sound signal in television) Sound broadcasting and the sound signal in television; telephony commercial grade, for connection to public service network; with privacy device . . . . . Telephony commercial grade, for connection to public service network; without privacy device. . . . . Telephony, not for connection to public service network . . . . .	P Q R
Continuous signal, e.g. telephony, telemetry, etc., coded to give a modulating signal in digital form . . . . .	S
Television (video only). . . . .	T
	U
	V
	W
	X
Modulating signal not described above . . . . .	Y
Two or more of the foregoing modulating signals, simultaneously or according to a pre-established sequence schedule; a modulating signal used for identification only being ignored	Z

TABLE III  
Examples

Note. — The symbols used in the formulae for bandwidth are defined in Appendix 5 to the Radio Regulations, Geneva, 1959.

Description	Present symbol	Proposed symbol
<p><i>Radionavigation and radio-determination systems, standard frequency emissions, etc., using a constant modulating signal</i> Non-keyed, non-modulated continuous-wave carrier, absence of modulating signal . . . . .</p>	A0	000AA
<p>Continuous-wave carrier, continuously amplitude-modulated by the modulating signal, consisting of a constant low frequency sinusoidal oscillation or oscillations: – double-sideband, full carrier: <math>M = 1000</math> c/s; <math>B_n = 2M = 2000</math> c/s . . . – single-sideband, full carrier: <math>M = 800</math> c/s; <math>B_n = M = 800</math> c/s . . . . .</p>	2A2 0-8A2H	202CB 801EB
<p>Continuous-wave carrier, continuously frequency-modulated by a modulating signal, consisting of a constant low frequency sinusoidal oscillation or oscillations; <math>2D = 800</math> c/s; <math>B_n = 2D = 800</math> c/s . . . . .</p>	0-8F2	801UB
<p>Non-keyed, non-modulated pulsed carrier: <math>B_n = \dots</math> . . . . .</p>	...P0	...PA
<p>Pulsed carrier, the pulses being continuously modulated by the modulating signal, consisting of a constant low frequency sinusoidal oscillation or oscillations. The low frequency sinusoidal oscillation modulates: – the amplitude of the pulses: <math>B_n = \dots</math> . . . . . – the width (or duration) of the pulses: <math>B_n = \dots</math> . . . . . – the phase (or position) of the pulses: <math>B_n = \dots</math> . . . . .</p>	...P2D ...P2E ...P2F	...QB ...RB ...SB
<p><i>Telegraphy, data transmission, etc., using a modulating signal comprising two-condition elements of pre-determined duration</i> On-off keying, by the modulating signal, of a continuous-wave carrier, without the use of any other modulation: – single channel, aural reception: <math>B = 20</math>, <math>K = 5</math>; <math>B_n = BK = 100</math> c/s – single channel, automatic reception, or time division multi-channels, aggregate speed 100 bauds: <math>B = 100</math>, <math>K = 5</math>, <math>B_n = BK = 500</math> c/s . . .</p>	0-1A1 0-5A1	101AC 501AD
<p>On-off keying by the modulating signal, of a low frequency sinusoidal oscillation which amplitude or frequency modulates a continuous-wave carrier; or by on-off keying, by the modulating signal, of the modulated emission: – single channel, aural reception: <math>B = 20</math>, <math>K = 5</math>; tone modulating in amplitude: <math>M = 1000</math> c/s, <math>B_n = BK + 2M = 2100</math> c/s . . . . . – tone modulating in frequency: <math>D = 500</math> c/s, <math>B_n = BK + 2D = 1100</math> c/s – single channel, automatic reception, or time-division multi-channel, aggregate speed, <math>B = 50</math>, <math>K = 5</math>; tone modulating in amplitude: <math>M = 1000</math> c/s, <math>B_n = BK + 2M = 2250</math> c/s . . . . .</p>	2-1A2 1-1F2 2-3A2	212BC 112BC 232BD

Description	Present symbol	Proposed symbol
Frequency-shift keying, by the modulating signal, of a continuous-wave carrier, between two conditions: – single channel or time-division multiplex channels, aggregate speed, $B = 50, D = 200$ c/s; $B_n = 2.1D + 1.9B = 515$ c/s . . . . . – single channel or time-division multiplex channels, aggregate speed, $B = 100, D = 100$ c/s; $B_n = 2.6D + 0.55B = 315$ c/s . . . . .	0.5F1  0.3F1	521UD  321UD
Frequency-shift keying, by the modulating signal of a continuous-wave carrier, between four conditions: two channels not synchronized, each channel with an aggregate speed: $B = 170, D = 600$ c/s; $B_n = 2.6D + 2.75B = 2027$ c/s . . . . .	2.03F6	202VF
Keying (any type of keying: on-off, amplitude, frequency-shift, etc.), by a modulating signal, of independent sub-carriers in frequency-division multiplex systems, which in turn amplitude-modulate a continuous-wave carrier: – single-sideband, suppressed carrier . . . . . – single-sideband, suppressed carrier, single sub-carrier (Note 1) . . . . . – single-sideband, reduced carrier . . . . . – single-sideband, reduced carrier, single sub-carrier . . . . . Single-sideband, reduced or suppressed carrier, the sub-carriers may be sub-channelled in time division (Note 2): $B = 100, D = 85$ c/s, $C = 2890$ c/s, $B_n = 3165$ c/s: – without automatic repetition . . . . . – with automatic repetition . . . . . Independent-sidebands, reduced or suppressed carrier, carrying one sub-carrier in each sideband; the sub-carriers may be sub-channelled in time-division (Note 2): $B = 100, D = 170$ c/s, $2C = 1870$ c/s, $B_n = 2367$ c/s: – without automatic repetition . . . . . – with automatic repetition . . . . . Independent-sidebands, reduced or suppressed carrier, carrying more than one sub-carrier in one or both sidebands; the sub-carriers may be sub-channelled in time-division (Note 2): $B = 100, D = 170$ c/s, $2C = 3430$ c/s, $B_n = 3727$ c/s: – without automatic repetition . . . . . – with automatic repetition . . . . .	. . . A2J . . . A7J . . . A2A . . . A7A  3.2A7A or A7J 3.2A7A or A7J  2.4A7B 2.4A7B  3.7A7B 3.7A7B	. . . A. . . . U. . . . G. . . . H.  322HD 322HE  242ID 242IE  372ID 372IE
On-off keying, by the modulating signal, of a low frequency sinusoidal oscillation modulating the pulses of a pulsed carrier; or by on-off keying, by the modulating signal, of the modulated pulsed carrier. The low frequency sinusoidal oscillation modulates: – the amplitude of the pulses: $B_n = \dots$ . . . . . – the width (or duration) of the pulses: $B_n = \dots$ . . . . . – the phase (or position) of the pulses: $B_n = \dots$ . . . . .	. . . P2D . . . P2E . . . P2F	. . . Q. . . . R. . . . S.
Two-condition facsimile, data transmission, etc., using as modulating signal two-condition elements of continuously variable duration On-off keying, by the modulating signal, of a low-frequency sinusoidal oscillation which amplitude-modulates a continuous-wave carrier or by on-off keying, by the modulating signal, of the modulated emission: $M = 1900$ c/s, $K = 1.5, N = 1100$ c/s, $B_n = KN + 2M = 5450$ c/s	5.5A4	552BN

Description	Present symbol	Proposed symbol
Frequency-shift keying, by the modulating signal of a continuous-wave carrier, between two conditions: $K = 1.5$ , $N = 1100$ c/s, $D = 400$ c/s, $B_n = KN + 2D = 2450$ c/s . . . . .	2.5F4	252UN
Frequency-shift keying, by the modulating signal, of a sub-carrier or sub-carriers, which amplitude-modulate a continuous-wave carrier: $M = 1900$ c/s, $K = 1.5$ , $N = 1100$ c/s, $D = 400$ c/s: - double-sideband, full carrier: $B_n = KN + 2M + 2D = 6250$ c/s . . . . . - single-sideband, full carrier: $B_n = KN + M + D = 3950$ c/s . . . . . - single-sideband, suppressed carrier, single sub-carrier: $B_n = KN + 2D = 2450$ c/s . . . . . - single-sideband, reduced carrier, single sub-carrier: $B_n = KN + 2D = 2450$ c/s . . . . . - independent-sidebands, reduced or suppressed carrier carrying one independent sub-carrier in each sideband: $B_n = KN + 2M + 2D = 6250$ c/s - independent-sidebands, reduced or suppressed carrier carrying more than one independent sub-carrier in one or both sidebands: $B_n = \dots$	6.3A4 4A4H 2.5A4J 2.5A4A 6.3A4B ...A4B	632CN 402EN 252UN (Note 1) 252GN 632IN ...JN
<i>Facsimile half-tones, analogue-data transmission, using a continuous variable modulating signal</i> Frequency or phase modulation, by the modulating signal, of a continuous-wave carrier: $K = 1.5$ , $N = 1100$ c/s, $D = 400$ c/s, $B_n = KN + 2D = 2450$ c/s. . . . .	2.5F4	252UO
Frequency, or phase, modulation, by the modulating signal, of a sub-carrier or sub-carriers which amplitude-modulates a continuous-wave carrier: $M = 1900$ c/s, $K = 1.5$ , $D = 400$ c/s: - double-sideband, full carrier: $B_n = KN + 2M + 2D = 6250$ c/s . . . . . - single-sideband, full carrier: $B_n = KN + M + D = 3950$ c/s . . . . . - single-sideband, suppressed carrier, single sub-carrier: $B_n = KN + 2D = 2450$ c/s . . . . . - single-sideband, reduced carrier, single sub-carrier: $B_n = KN + 2D = 2450$ c/s . . . . . - independent-sidebands, reduced or suppressed carrier, carrying one independent sub-carrier in each sideband: $B_n = KN + 2M + 2D = 6250$ c/s - independent-sideband, reduced or suppressed carrier, carrying more than one independent sub-carrier in one or both sidebands: $B_n = \dots$	6.3A4 4A4H 2.5A4J 2.5A4A 6.3A4B ...A4B	632CO 402EO 252UO (Note 1) 252GO 632IO ...JO
<i>Telephony</i> Amplitude-modulation, by the modulating signal, of a continuous-wave carrier, for connection to public network, privacy device: $M = 3000$ c/s: - double-sideband, full carrier: $B_n = 2M = 6000$ c/s . . . . . - single-sideband, full carrier: $B_n = M = 3000$ c/s . . . . . - single-sideband, reduced or suppressed carrier, single channel: $B_n = M = 3000$ c/s . . . . . - single-sideband, reduced or suppressed carrier, multi-channels in frequency-division arrangement, 2 channels: $B_n = 2M = 6000$ c/s. . . . .	6A3 3A3H 3A3A or 3A3J 6A3A or 6A3J	602CP 302EP 302GP 602HP

Description	Present symbol	Proposed symbol
<ul style="list-style-type: none"> <li>- independent-sidebands, reduced or suppressed carrier, carrying one channel in each sideband: <math>B_n = 2M = 6000</math> c/s . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier, carrying more than one channel in frequency-division arrangement in one or both sidebands:               <ul style="list-style-type: none"> <li>3 channels: <math>B_n = 3M = 9000</math> c/s. . . . .</li> <li>4 channels: <math>B_n = 4M = 12\ 000</math> c/s . . . . .</li> </ul> </li> </ul>	<p>6A3B</p> <p>9A3B 12A3B</p>	<p>602IP</p> <p>902JP 123JP</p>
<p>Amplitude-modulation, by the modulating signal of a continuous-wave carrier, for connection to the public network, without privacy device: <math>M = 3000</math> c/s:</p> <ul style="list-style-type: none"> <li>- double-sideband, full carrier: <math>B_n = 2M = 6000</math> c/s . . . . .</li> <li>- single-sideband, full carrier: <math>B_n = M = 3000</math> c/s . . . . .</li> <li>- single-sideband, reduced or suppressed carrier, single channel: <math>B_n = M = 3000</math> c/s . . . . .</li> <li>- single-sideband, reduced or suppressed carrier, multi-channels in frequency-division arrangement, 2 channels: <math>B_n = 2M = 6000</math> c/s. . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier, carrying one channel in each sideband: <math>B_n = 2M = 6000</math> c/s . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier, carrying several channels in frequency-division arrangement in one or both sidebands:               <ul style="list-style-type: none"> <li>3 channels: <math>B_n = 3M = 9000</math> c/s. . . . .</li> <li>4 channels: <math>B_n = 4M = 12\ 000</math> c/s . . . . .</li> </ul> </li> </ul>	<p>6A3 3A3H</p> <p>3A3A or 3A3J</p> <p>6A3A or 6A3J</p> <p>6A3B</p> <p>9A3B 12A3B</p>	<p>602CQ 302EQ</p> <p>302GQ</p> <p>602HQ</p> <p>602IQ</p> <p>902JQ 123JQ</p>
<p>Amplitude-modulation, by the modulating signal, of a continuous-wave carrier, not for connection to the public service network:</p> <ul style="list-style-type: none"> <li>- double-sideband, full carrier: <math>B_n = 2M = 6000</math> c/s . . . . .</li> <li>- single-sideband, full carrier: <math>B_n = M = 3000</math> c/s . . . . .</li> <li>- single-sideband, reduced or suppressed carrier, single channel: <math>B_n = M = 3000</math> c/s . . . . .</li> <li>- single-sideband, reduced or suppressed carrier, multi-channels in frequency-division arrangement, 2 channels: <math>B_n = 2M = 6000</math> c/s. . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier, carrying one channel in each sideband: <math>B_n = 2M = 6000</math> c/s . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier, carrying several channels in frequency-division arrangement in one or both sidebands:               <ul style="list-style-type: none"> <li>3 channels: <math>B_n = 3M = 9000</math> c/s. . . . .</li> <li>4 channels: <math>B_n = 4M = 12\ 000</math> c/s . . . . .</li> </ul> </li> </ul>	<p>6A3 3A3H</p> <p>3A3A or 3A3J</p> <p>6A3A or 6A3J</p> <p>6A3B</p> <p>9A3B 12A3B</p>	<p>602CR 302ER</p> <p>302GR</p> <p>602HR</p> <p>602IR</p> <p>902JR 123JR</p>
<p>Frequency-modulation by the modulating signal, of a continuous-wave carrier, not for connection to the public service network: <math>M = 3000</math> c/s, <math>D = 15\ 000</math> c/s, <math>K = 1</math>, <math>B_n = 2M + 2DK = 36\ 000</math> c/s . . . . .</p>	36F3	363UR
<p><i>Sound broadcasting</i></p> <p>Amplitude-modulation, by the modulating signal, of a continuous-wave carrier: <math>M = 6000</math> c/s:</p> <ul style="list-style-type: none"> <li>- double-sideband, full carrier: <math>B_n = 2M = 12\ 000</math> c/s . . . . .</li> <li>- single-sideband, full carrier: <math>B_n = M = 6000</math> c/s . . . . .</li> <li>- single-sideband, reduced or suppressed carrier: <math>B_n = M = 6000</math> c/s . . . . .</li> </ul> <p>Frequency-modulation, by the modulating signal, of a continuous-wave carrier: <math>M = 15\ 000</math> c/s, <math>D = 75\ 000</math> c/s, <math>K = 1</math>, <math>B_n = 2M + 2DK = 180\ 000</math> c/s . . . . .</p>	<p>12A3</p> <p>6A3H 6A3A or 6A3J</p> <p>180F3</p>	<p>123CP 602EP 602GP</p> <p>184UP</p>

Description	Present symbol	Proposed symbol
<p><i>Television (Vision)</i></p> <p>Amplitude-modulation, by the modulating signal, of a continuous-wave carrier; full carrier, vestigial-sideband, 625-lines: <math>B_n = 6.25</math> Mc/s. . . .</p> <p>Frequency-modulation, by the modulating signal, of a continuous wave:  <math>B_n = \dots</math> . . . . .</p>	<p>6250A5C</p> <p>...F5</p>	<p>635ET</p> <p>...UT</p>
<p><i>Emissions carrying a variety of modulating signals</i></p> <p>Continuous-wave carrier, amplitude-modulated, according to a pre-established sequence schedule, by miscellaneous modulating signals, as for standard frequency emissions consisting of one or more low frequency oscillations, digital signals, telephony, etc.:</p> <ul style="list-style-type: none"> <li>- double-sideband, full carrier: <math>B_n = \dots</math> . . . . .</li> <li>- single-sideband, full carrier: <math>B_n = \dots</math> . . . . .</li> <li>- single-sideband, reduced or suppressed carrier: <math>B_n = \dots</math> . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier: <math>B_n = \dots</math> . . . . .</li> </ul>	<p>...A9</p> <p>...A9H</p> <p>...A9A or ...A9J</p> <p>...A9B</p>	<p>...CZ</p> <p>...EZ</p> <p>...GZ</p> <p>...IZ</p>
<p>Continuous-wave carrier, amplitude-modulated simultaneously by independent sub-carriers carrying miscellaneous modulating signals, as for frequency-division multiplex systems, with constant frequency arrangements of communication channels or sub-carriers, consisting of alpha-numerical telegraphy, data transmission, telephony, etc.:</p> <ul style="list-style-type: none"> <li>- double-sideband, full carrier: <math>B_n = \dots</math> . . . . .</li> <li>- single-sideband, full carrier: <math>B_n = \dots</math> . . . . .</li> <li>- single-sideband, reduced or suppressed carrier: <math>B_n = \dots</math> . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier: <math>B_n = \dots</math> . . . . .</li> </ul>	<p>...A9</p> <p>...A9H</p> <p>...A9A or ...A9J</p> <p>...A9B</p>	<p>...DZ</p> <p>...FZ</p> <p>...HZ</p> <p>...JZ</p>
<p>Continuous-wave carrier, frequency-modulated: <math>B_n = \dots</math> . . . . .</p>	<p>...F9</p>	<p>...UZ or ...VZ</p>
<p><i>Emissions carrying a modulating signal, not described in this Table</i></p> <p>Continuous-wave carrier amplitude-modulated:</p> <ul style="list-style-type: none"> <li>- double-sideband, full-carrier: <math>B_n = \dots</math> . . . . .</li> <li>- independent-sidebands, reduced or suppressed carrier: <math>B_n = \dots</math> . . . . .</li> </ul>	<p>...A9</p> <p>...A9B</p>	<p>...CY or ...DY</p> <p>...IY or ...JY</p>
<p>Continuous-wave carrier, frequency-modulated: <math>B_n = \dots</math> . . . . .</p>	<p>...F9</p>	<p>...UY or ...VY</p>
<p><i>Carrier bearing two or more types of modulation and a variety of modulating signals</i> . . . . .</p> <p><i>Carrier modulated by processes not described in this Table by a particular modulating signal.</i> . . . . .</p> <p><i>Carrier modulated by processes and modulating signals not described in this Table</i> . . . . .</p>		<p>...ZZ</p> <p>...YB to ...YT</p> <p>...YY</p>

*Note 1.* – Single-sideband emissions with suppressed carrier modulated only by a single sub-carrier are classified as if the sub-carrier were the main carrier.

*Note 2.* – For this class of emission, the formula for necessary bandwidth is not yet defined in Appendix 5 of the Radio Regulations, Geneva, 1959, and it depends on the sub-carriers arrangement and on the keying.

In those examples, the following approximative formula for necessary bandwidth has been used, assuming the extreme sub-carriers at each end of the occupied band are frequency-shift keyed,  $B$  being their highest standard speed in bauds and  $D$  the frequency deviation in c/s:

$$B_n = 2.6 D + 0.55 B + C, \text{ for single-sideband,}$$

$$B_n = 2.6 D + 0.55 B + 2 C, \text{ for independent-sideband;}$$

where  $C$  is the highest sub-carrier frequency in c/s, and  $2 C$  is the separation in c/s between the highest sub-carrier frequency on the upper band and the highest sub-carrier frequency on the lower band.

## ANNEX I

SYSTEMATIC LIST OF THE CHARACTERISTICS WHICH DESCRIBE AN EMISSION,  
ARRANGED AS FAR AS POSSIBLE IN THE ORDER OF ELECTRICAL OPERATIONS

### *Examples*

#### 1. Input signal

- 1.1 *Type of signal* : Telegraphy, telephony, television, facsimile, telemetering, telecommand.
- 1.2 *Signal coding* : Morse, 5-unit teleprinter, 7-unit alphabet, telephony signal, music signal, coded speech, etc.
- 1.3 *Numerical and other characteristics*
  - 1.3.1 *Speed* :  $N$  bauds.
  - 1.3.2 *Quality* : Telegraph error rate, high quality service or commercial channel, or broadcasting over a telephony circuit.

#### 2. First modulation

- 2.1 *Type of modulation* : Amplitude, frequency, phase, position modulated pulses, etc.
- 2.2 *Carriers*
  - 2.2.1 *Carrier frequency position*.
  - 2.2.2 *Relative amplitude of carriers* : Full. Reduced. Suppressed.
  - 2.2.3 *Other numerical characteristics* : Modulation rate and level, frequency deviation, modulation index, pulse repetition rate, etc.

#### 2.3 Sub-carriers

- |       |   |                  |
|-------|---|------------------|
| 2.3.1 | } | as for carriers. |
| 2.3.2 |   |                  |
| 2.3.3 |   |                  |

#### 3. First multiplexing

- 3.1 *Type of multiplexing* : Time-division, frequency-division.
- 3.2 *Variable or non-variable (for frequency-division)* : See Recommendation 347.
- 3.3 *Interleaving (for time-division)* : See Recommendation 342.
- 3.4 *Number of channels*.

- 3.5 *Numerical characteristics* :
  - 3.5.1 *Width of each channel* :
  - 3.5.2 *Duration of each pulse* :
  - 3.5.3 *Duration of each cycle* :
- 4. **Second modulation** (as § 2)
- 5. **Second multiplexing** (as § 3)
- 6. **Third modulation** (as § 2)

## ANNEX II

### CLASSIFICATION OF EMISSIONS *List of minimum essential characteristics*

#### 1. Introduction

Annex I gives, in summary form, a list of all the characteristics, showing the process from the signal input to the final emission.

Annex II is an attempt to state which of these characteristics are considered *essential* for the purpose of classification.

The characteristics considered essential are those describing the form of the emission; it is not necessary to know all the various intermediate stages of modulation and multiplexing. The information which is given should be sufficient to distinguish between different radio systems, which require different minimum values of protection ratio for satisfactory operation, as well as those which have different potentialities for causing interference to other radio circuits.

In the following list of characteristics, an asterisk, \*, indicates "characteristics stated as supplementary information", i. e., not adequately described by the items listed.

Although coding is not discussed, the desirability of putting all the information in 11 positions in column 7 of the Master International Frequency Register has been borne in mind.

#### 2. Input signal

The "input", in the sense used here, may not be the input to the radio transmitter; it may be the input to multiplexing apparatus located separately from the radio transmitter. The input is considered to consist of a stated number of channels.

##### 2.1 *Type and characteristics of the input signal*

- a - telephone, operator-to-operator, no privacy, nominal bandwidth approximately 3 kc/s;
- b - telephone, connected to land-line network, with privacy, nominal bandwidth approximately 3 kc/s;
- c - telephone \*;
- d - programme material (state the nominal bandwidth);
- e - telegraph, manual;
- f - telegraph, teleprinter;
- g - telegraph, teleprinter, ARQ;
- h - telegraph, Hellschreiber;
- i - telegraph, recorder;
- j - telegraph \*;
- k - telegraph \*;
- l - telegraph \*;

- m – telegraph \*;
- n – data, two-position signal approximately periodic;
- o – data \*;
- p – facsimile, phototelegraphy, Grade I;
- q – facsimile, phototelegraphy, Grade II;
- r – \*;
- s – television, monochrome, 405–lines;
- t – television, monochrome, 525–lines;
- u – television, monochrome, 625–lines;
- v – television, monochrome, 819–lines;
- w – \*;
- x – \*;
- y – \*;
- z – \*.

## 2.2 Numerical characteristics of the input signal

2.2.1 Number of channels (e. g. telephone, telegraph, etc.; see § 2.).

2.2.2 If appropriate, the number of shortest elements per second in each input channel, i. e. for telegraphy, the highest keying speed per channel.

*Note.* – A large number of digits will be required to code this information, which must therefore be a minimum.

## 3. Principal features of the emission

### 3.1 Radiated carrier, unmodulated

- a – carrier, unmodulated.

### 3.2 Radiated carrier amplitude-modulated

- b – on-off keying of carrier;
- c – varying modulating signal, such as speech or television, etc., with carrier approximately central;
- d – varying modulating signal, such as speech or television, etc., with carrier at upper edge of band;
- e – varying modulating signal, such as speech or television, etc., with carrier at lower edge of band;
- f – varying modulating signal, such as speech or television, etc., asymmetric sidebands \*;
- g – one modulating audio tone, the carrier and audio tone being keyed;
- h – one modulating audio tone which is keyed, the carrier being unkeyed;
- i – one modulating audio tone, no keying;
- j – with radiated sub-carriers as described in § 4.1 and ...;
- k – direct amplitude-modulation by facsimile or phototelegraph signals;
- l – \*.

### 3.3 Reduced or suppressed carrier, amplitude-modulated

- m – carrier reduced (Note 1) or suppressed; single-sideband or independent-sideband emission with one or more principal frequency sub-divisions (Note 2) of the emission;

### 3.4 Carrier, frequency-modulated

- o – two conditions;
- p – several, usually 4 or 5 conditions;
- q – varying modulating signal, such as speech or television, described in § 4 or § 2;
- r – complex modulating signal, consisting of several time-division multiplex channels, described in § 4;
- s – \*;
- t – \*.

3.5 *Carrier, phase-modulated*

- u – two conditions;
- v – several, usually 4 or 5 conditions;
- w – varying modulating signal, such as speech or television, described in § 4 or § 2;
- x – complex modulating signal, consisting of several time-division multiplex channels, described in § 4;
- y – \*;
- z – \*.

*Note 1.* – Reduced by 10 db or more.

*Note 2.* – The term “ principal sub-divisions ” is used to indicate the largest units of sub-division of the emission. For single-sideband and independent-sideband emissions, in the frequency bands between about 3 Mc/s and about 30 Mc/s, the “ principal sub-divisions ” are often bands about 3 kc/s wide.

3.6 *Numerical characteristics*

- 3.6.1 Number of sub-carriers or of principal sub-divisions;
- 3.6.2 For amplitude-modulated systems including single-sideband and independent-sideband systems: the position of the carrier (except when indicated by § 3.2, c, d or e);
- 3.6.3 For frequency-modulation systems only: frequency deviation, or frequency shift or phase deviation.

*Note.* – A large number of digits will be required to code this information, which must therefore be a minimum.

4. **Composition of principal sub-divisions, and characteristics of sub-carriers and their modulation**

4.1 *Frequency-division multiplex groups*

*Note.* – The term “ groups ” is used in a general sense (and not in contradistinction from, for example, supergroups).

- a – group of voice-frequency telegraph or data-transmission channels, each with on-off keying;
  - b – group of voice-frequency telegraph or data-transmission channels, each with frequency modulation (i. e. frequency shift);
  - c – group of voice-frequency telegraph or data-transmission channels, with two-tone operation (i. e. two tones per channel, each tone of a pair keyed on-off in antiphase);
  - d – group of voice-frequency telegraph or data-transmission channels \*;
  - e –
  - f –
  - g –
  - h –
- as a to d, but each “ channel ” consisting of a group of multiplexed channels, described in § 5;
- i – group of telephone channels;
  - j – group of facsimile channels, or of sub-carriers each carrying facsimile, each sub-carrier being amplitude-modulated;
  - k – group of facsimile channels, or of sub-carriers each carrying facsimile, each sub-carrier being frequency-modulated;
  - l – group of sub-carriers carrying telemetering or telecommand signals;
  - m – \*;
  - n – \*;
  - o – \*;
  - p – \*.

#### 4.2 Time-division multiplex

- q – group of time-division multiplex telegraph or data channels, each channel consisting, at its input, of a single telegraph or data input channel; described in § 2;
- r – group of time-division multiplex telegraph or data channels, each channel consisting, at its input, of a multiplex group of telegraph or data channels; described in § 5;
- s – group of time-division multiplex channels carrying telemetering or telecommand signals; described in § 2;
- t – \*;
- u – \*;
- v – \*;
- w – \*.

#### 4.3 Numerical characteristics of multiplexed groups or groups of sub-carriers

- 4.3.1 Number of input channels to the multiplexed group (each input channel may itself be multiplexed), or number of sub-carriers.
- 4.3.2 (If appropriate), frequency deviation of sub-carrier(s).
- 4.3.3 (If appropriate), frequency separation between channels or sub-carriers.

*Note.* – A large number of digits will be required to code this information, which must therefore be a minimum.

#### 5. Further sub-divisions

If the information listed in § 2 concerning the input signal (number of channels, baud speed per channel, etc.) is given, and the information listed in § 4 for the characteristics of multiplex groups in the principal sub-division of the spectrum is also given, there will not usually be any need to give details of intermediate stages of multiplexing. However, if considered necessary for the purposes of deciding the protection ratio and interfering potentiality of an emission, further particulars can be given in a form similar to that of § 4.

#### 6. Pulse-modulation systems

Further consideration is necessary to decide whether additional data are required concerning pulse-modulation systems.

#### 7. Summary

Although the question of coding is not discussed in this Report, it is convenient to write a summary in terms of a possible coding in 11 positions in column 7 of the Master International Frequency Register.

- 1 – } bandwidth information;
- 2 – }
- 3 – type and characteristics of the input signal;
- 4 – numerical characteristics of the input signal;
- 5 – content of the emission;
- 6 – numerical characteristics of the emission;
- 7 – composition of groups of multiplexed signals;
- 8 – numerical characteristics of multiplexed groups;
- 9 – } further multiplexing, corresponding to positions 6 and 7 (if needed);
- 10 – }
- 11 – available for additional information, including that indicated by \* in the text.

The sequence or order of appearance, and the type of symbolization, is not discussed in this Report.

REPORT 176 \*

**COMPRESSION OF THE RADIOTELEPHONE SIGNAL SPECTRUM  
IN THE HF BANDS**

(Question 219(I))

(Geneva, 1963)

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 of 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 bandwidth, 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 of 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.

All the speech compression systems require complex terminal equipment, both at the transmitter and receiver, and at the present state of the art, the cost would seem to be justified only for a large number of telephone channels.

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 compared to double-sideband systems, and unlike a number of other spectrum reducing systems, it is well suited to high-frequency radiotelephone transmission. 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. Practical development of such systems should be strongly encouraged.

---

\* This Report was adopted unanimously.

\*\* BEERY, W.M. and NESENBERGS, M., *National Bureau of Standards, Report 7296.*

\*\*\* See Recommendations 100 and 330.

## REPORT 177 \*

**COMPRESSION OF THE RADIOTELEGRAPH SIGNAL SPECTRUM  
IN THE HF BANDS**

(Question 220(I))

(Geneva, 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.) of 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 c/s have been widely used and are successful. A somewhat similar system is now proposed using four frequencies with a spacing of only 80 c/s. Diplex keying, with 10 ms elements, is used 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.

---

\* This Report was adopted unanimously.

#### 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 \*

#### POSSIBILITIES OF REDUCING INTERFERENCE AND OF MEASURING ACTUAL TRAFFIC SPECTRA

(Study Programme 181(I))

(Warsaw, 1956 – Los Angeles, 1959 – Geneva, 1963)

#### 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 fulfills 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 fulfill 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 time spectrum whose envelope is the spectrum of the elementary signal and, in the second case, a spectrum identical to that of the elementary signal.

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

---

\* This Report, which replaces Report 96, 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 a particular definition for signal duration and bandwidth, showed that the best elementary signal in those respects was a signal having the shape of a Gaussian curve. Such a shape can be approached, as closely as required, by using multiple-section filters, either with a very simple iterative filter section or non-iterative sections, although a large number of sections introduces a signal delay which is the only parameter limiting the practical application of the method. Nevertheless, delays of not more than one word of medium length should be very 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 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 emissions, except those using frequency modulation, a simple relation can thus be established between the output radio signal and the input modulating signal. Consequently, the following considerations and results are not, in general, applicable to frequency modulation.

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

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

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

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

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

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

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

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

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

---

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

The effect of the signal on receivers of fairly small bandwidth, which integrate the amplitudes or the powers, can be easily assessed when the spectrum of the elementary signal and also the first (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 equal power in a given band, this is the most damaging form of interference, since it causes the greatest loss of capacity in the channel under consideration.

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

If, on the other hand, the signal is correlated, a term depending on the frequency is added to the preceding constant which represents the mean signal power. If, as before, we assume that the receiver subject to interference of the spectrum 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 at 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 integer function, if (as is always the case in practice), the signal has traversed a passive quadripole. This is because an actual signal is null before the finite instant at which the message begins, is always bounded and after passage through the passive quadripole falls off exponentially towards zero from the moment the message ends.

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

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

- (a) The problem of interference will always exist. Since the spectrum of an actual signal cannot be zero in any frequency interval, any receiver tuned close to the carrier of any actual emission receives energy therefrom. If the frequency difference is large enough, this energy may be small, and sometimes negligible, but it can never be zero.
- (b) The effect of interference on a receiver cannot be assessed if we know merely the energy received from the interfering station. It will depend on the nature of the signal transmitted and on the kind of receiver.

Only in one case is the effect of the interfering station very simple; when the receiver passband can be 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 amplitudes, 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 amplitudes, statistically independent of each other, it is possible to measure the spectra of the random signals and to obtain stable results, readily comparable with those obtained by measuring the spectrum of an elementary signal or of the periodic elementary signals applied to the same transmitting system, provided that the indicator of the spectrum 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 analyzer is used. The oscillations have a complicated relationship with the bandwidth and filter characteristics of the analyzer, 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 isolated points of the spectrum of the single pulse, which is the envelope of the line spectrum of the periodic pulses.

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

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

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

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

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

### 3. Reduction of out-of-band radiation

If nothing is known about the characteristics of the receiver suffering from interference, or if the person transmitting is unfamiliar with the system used by the circuit 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 fulfill 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 fairly long actual signal, with a roughly Gaussian statistical distribution, can give a very weak spectrum outside a certain band; this would represent minimum interference. All that would be required, would be to filter it in a suitable way and it can be deduced from the above that this filtering would be possible without inordinately affecting the signal, but that the reduction of the out-of-band radiation would be achieved only at the cost of a delay of the signal and would be greater as the delay was increased.

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

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

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

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

#### 4. Reduction of bandwidth

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

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

subsequently, to be prolonged indefinitely and vanish progressively, in accordance with an exponential law. The spectra of these latter signals cannot be zero outside any given band.

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

To facilitate formulation of the problem, other concepts which may be equivalent to "build-up time" 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, in addition, our aim is to find an elementary signal with a minimum duration and as narrow a spectrum as possible, the required conditions must be fulfilled, in the Gabor sense, by signals which make the uncertainty product near to unity. It has recently been shown that this relation is only exact when the spectrum function is zero for frequency zero [8]. This is not usually so, but in the radio case under consideration where the r.m.s. spectrum width is negligible with respect to the carrier frequency, the spectrum energy is almost zero for frequency zero and the Gabor relation is fully applicable. The corrective term should not be considered unless the same theory is to be applied, for example, to carrier frequency telegraph systems, 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 signals. However, these signals are not, strictly speaking, Gaussian signals; the considerations above have shown that in telegraphy, each telegraph instant should be transmitted by a Gaussian signal with joined elements, represented by successive elementary signals of such a length as to ensure that the resulting undulation on the signal along the maximum is small. In a more recent contribution [15], the same author, comparing several shapes of signal, shows that the higher the degree of the first term of its power series expansion, the weaker the interference caused by the signal. This property is very general: a reduction in out-of-band radiation required a rapid decrease in the spectrum with movement away from its centre: the order of asymptotic decrease of the spectrum is equal to the order of the tangent at the origin of the signal beginning at the origin of time [16]. The signal delay, on the other hand, increases with the degree of the first term of its power series expansion. Thus, the quite basic principle in the theories of Shannon and Gabor is once again confirmed, whereby the interference can be reduced only if the signal is delayed, the best results being obtained when the delay is infinite (that is, of course, when there is no telecommunication whatsoever).

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

Chalk [13], 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 cosine 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, if one considers the adaptation of the signal itself, to its transmission in the minimum bandwidth. In particular, in this respect, if "optimum coding" is sought, it can be shown that the signal must be delayed. The same applies if the signal is to be transmitted after frequency compression and to be expanded when received. The importance of delay has been stressed in the latest version of a C.C.I.R. question on information theory [20].

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

optimum. Wheeler and Loughren [11] were the first to propose the use of clipped sine-wave signals for television, but their justification was empirical.

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

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  $\epsilon^2$  of their energy in a finite interval of time  $T$  can be expanded in a series of  $2WT$  "prolate spheroidal wave functions", with a total integrated squared error less than  $12\epsilon^2$ . 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 attendant distortion of the signal. The quality of the signal itself is fully defined by the form of the elementary signal, i. e. the shortest signal that can be emitted by the quadripole representing the transmitter. But it is at the output of the receiver that the desired quality of the signal must be maintained. Hence, in interference problems, we have to consider not only the characteristics of the receiver suffering interference, but also those of the correspondent's receiver, which in many cases can be represented, like the transmitter, by linear quadripole (the most important exceptions are the cases in which frequency-modulation is used).

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

The problem is easier if we assume two identical receivers. We can then assume, that since two identical receivers are in principle designed to receive two signals of the same kind, the transmitters are also identical. We shall then be able to inquire under what conditions the mutual interference between two such circuits of the same nature is minimum, when they operate on neighbouring frequencies. If we make some extra assumptions—we shall not go into them here, since they do not appear to affect the general validity of the result obtained—Villepelet [21] has shown that, in these circumstances, the mutual interference is minimum when the equivalent quadripoles representing each transmitter and each receiver are identical. This result fully determines the quadripoles, for we can also look for the optimum form of the filter to be used (as mentioned above), together with the minimum bandwidth and the

maximum delay which will retain the desired signal quality. The quadripole thus defined represents the unit transmitter-receiver. If iterative, it will suffice to cut it in two, allocating an equal number of sections to the transmitter and to the receiver, to obtain Villepelet's optimum. With present-day equipment, at least in radiotelegraphy and broadcasting \*, this optimum is very far from being attained. Receivers are in general equipped with relatively narrow filters, with rather steep slopes, while transmitters are filtered little or not at all. The rest of Villepelet's paper shows the drawbacks of this inadequate filtering in every case.

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

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

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

We must not generalize and assume that this is only one instance of a general principle, according to which circuits of the same kind should always work on adjacent channels. In the present state of theory, there is no justification for such principle. Indeed, there are

---

\* 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.

several reasons why it may be, in part at least, false. If, for example, we consider a synchronous telegraph circuit, it would seem that an excellent source of interference would be an emission of the same type, of the same speed, and with its characteristic instants synchronized, the messages being, of course, independent (telegraph apparatus can respond to false signals only when they are more or less synchronized with their distributors). Here white noise is not necessarily the best source of interference, because the spectrum of the signal cannot be assimilated to a limited, uniform spectrum.

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

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

In practice, all existing receivers are designed to receive and decode the desired signal as well as possible. Protection is only envisaged against white noise, never against interference of other kinds, which may be very different, except, for instance, with multiplex, in which the adjacent channel belongs to the same system. Now, since interference is inevitable, it would conceivably be of advantage, in some cases at least, to determine the receiver characteristics to suit both the signal to be received and the interference. This will be feasible, only if the interference is of a particular kind, or at least has characteristics of a certain kind. It is inconceivable that the receiver should reject an interfering signal by making a distinction between it and the signal wanted, 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 radio-telephone signal. If we know accurately the frequency (stable) of the interference, the only parameter on which it depends, we shall be able to filter it by a very narrow filter neutralizing a very small receiver frequency band without, in practice, affecting, as we know, the reception of the signal wanted.

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.

## BIBLIOGRAPHY

1. LEVY, P. *Théorie de l'addition des variables aléatoires*. Gauthier-Villars (Paris).
2. MARIQUE, J. Réponse des analyseurs de spectres radioélectriques à des signaux Morse non périodiques. *Annales des Télécommunications* (July-August, 1954 and September, 1954).

3. BLANC-LAPIERRE and FORTET. *Théorie des fonctions aléatoires*. Masson (Paris).
4. SHANNON, C. E., and WEAVER, W. *A mathematical theory of communication*. University of Illinois Press (1949).
5. SHANNON, C. E. Communication in the presence of noise. *Proc. IRE*, **37**, 10 (1949).
6. KOLMOGOROV, A. N. *Theory of communications*. Editions of the Academy of Sciences, Moscow (1956). *Arbeiten zur Informations-theorie, I*. VEB, Deutscher Verlag der Wissenschaften, Berlin (1957).
7. GABOR, D. Theory of communications. *J.I.E.E.*, Part III, **93**, 429–457 (November, 1946).
8. KAY, I. and SILVERMAN, R. A. On the uncertainty relation for real signals. *Information and Control*, Vol. 1, **1**, 64–75 (September, 1957).
9. VASSEUR. Impulsions de Gauss. *Annales de Radioélectricité* (October, 1953).
10. INDJOUJIAN. Réseau de mise en forme d'impulsions électriques, French Patent 660.505 (22 December, 1953). Réseau électrique de retard. Patent of same date.
11. WHEELER and LOUGHREN. *Proc. IRE* (May, 1938).
12. ROBERTS and SIMMONDS. *Philosophical Magazine*, 822–827 (1943) and 459–470 (1944).
13. CHALK. The optimum pulse-shape for pulse communications. *Proc. I.E.E.*, Part III, Vol. **97**, **46** (March, 1950).
14. MARIQUE, J. Forme des signaux radiotélégraphiques et interférence entre voies adjacentes. *Annales des télécommunications* (February, 1956).
15. Doc. 9 (Belgium) of Warsaw, 1956.
16. VAN DER POL, B. and BREMMER, H. *Operational calculus*. Chapter VII, Cambridge University Press.
17. GOUREVITCH, M. S. Signals of finite duration with a maximum energy in a particular band. *Review of the U.S.S.R. Academy of Sciences, Radio and Electronics*, Vol. I, **3** (1956). The frequency band occupied by a pulse transmission. Same Review, Vol. II, **1** (1957). (Summary of the results given by Doc. I/38 of Geneva, 1958).
18. Doc. 120 (U.S.S.R.) of Los Angeles, 1959.
19. VILLE, J. A., and BOUZITAT, J. Note sur un signal de durée finie et d'énergie filtrée maximum. *Câbles et Transmissions*, Vol. 11, **2** (April, 1957).
20. Question 133 (III): Communication theory, Warsaw, 1956.
21. VILLEPELET, J. Etude théorique et expérimentale du brouillage mutuel entre systèmes de radio-communications. *Annales des télécommunications*, Vol. **10**, **12** (December, 1955) and Vol. **11**, **1** (January, 1956) (Summarised for the C.C.I.R. in Doc. 174 of Warsaw, 1956).
22. BLACHMAN, N. M. Communication as a game. *IRE Wescon Convention Record*, **61** (1957).
23. DEMAN, P. Spectre instantané et analyse du signal simultanément en fréquence et en temps. *U.R.S.I.*, Boulder, Colorado (1957).
24. SLEPIAN, D. and POLLAK, H. O. Prolate spheroidal wave functions, Fourier analysis and uncertainty. Part I, *B.S.T.J.*, **40**, 43–63 (January 1961).
25. LANDAU, H. J. and POLLAK, H. O. Same title, Part II, *B.S.T.J.*, **40**, 65–84 (January 1961).
26. LANDAU, H. J. and POLLAK, H. O. Same title, Part III, *B.S.T.J.*, **41**, 1295–1336 (July, 1962).

---

REPORT 179 \*

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

(Study Programme 181(I))

(Los Angeles, 1959 – Geneva, 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.

---

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

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) of Geneva, 1958), describes the spectrum distribution of F1 emission in detail, and deals with the occupied bandwidth.

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

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

where

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

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

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

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

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

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

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

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

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

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

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

where  $\alpha$  = 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) of Geneva, 1951:

$$\begin{aligned} & 3\% \text{ for } \alpha = 0 \quad ; 2 \leq m \leq 20 \\ & 9\% \text{ for } \alpha = 0.08; 1.4 \leq m \leq 20 \\ & 10\% \text{ for } \alpha = 0.24; 2 \leq m \leq 20 \end{aligned}$$

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, § 1.2.

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

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

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

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

#### 3.1 Spectra and filtering of A1 emissions

The 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 of 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 synchronisation 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	$\infty$

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 duplex); 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
Radioteletypewriter 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.

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

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

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

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

$f$ : frequency difference between the 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  $Y(f - \Delta f)$ . This admittance is centred on the nearest working or resting frequencies where  $f = \Delta f$ . The values of  $Y(f)$  are shown in Fig. 6.

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

$F$ : 6 db bandwidth of intermediate-frequency of the receiver.

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

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

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

Fig. 8 shows some results obtained with this formula.

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

#### 4. Measurements on spectra of F1 signals

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

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

In Doc. I/6 (Federal Republic of Germany) of Geneva, 1962, it was shown that the bandwidth limitations, set forth in §§ 2.1 and 2.5 of Recommendation 328, 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 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.

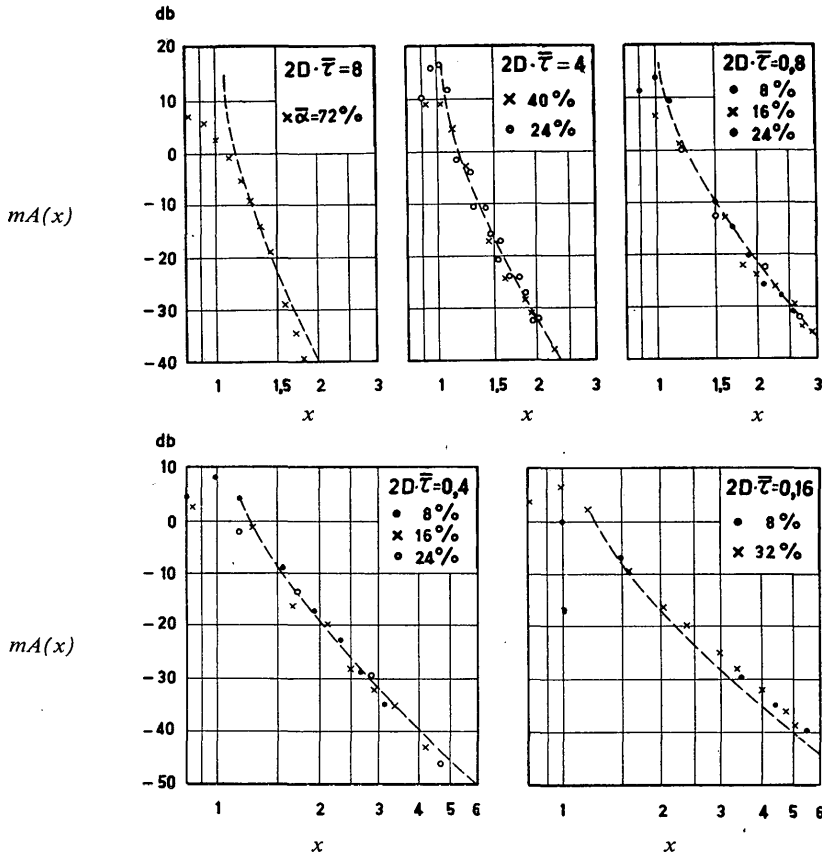


FIGURE 1 — Spectra of FI emissions  
 — — — — — Calculated from empirical formula (1).  
 • ◦ × Measured points.

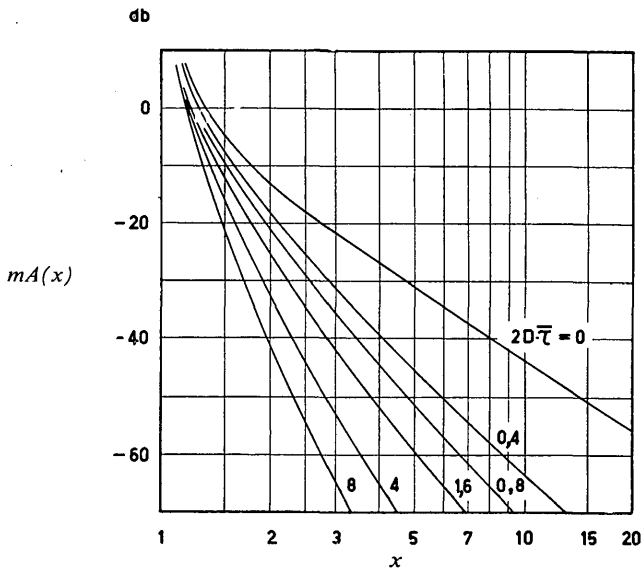


FIGURE 2  
 Spectrum distribution of FI emission  
 calculated from empirical  
 formula (1)

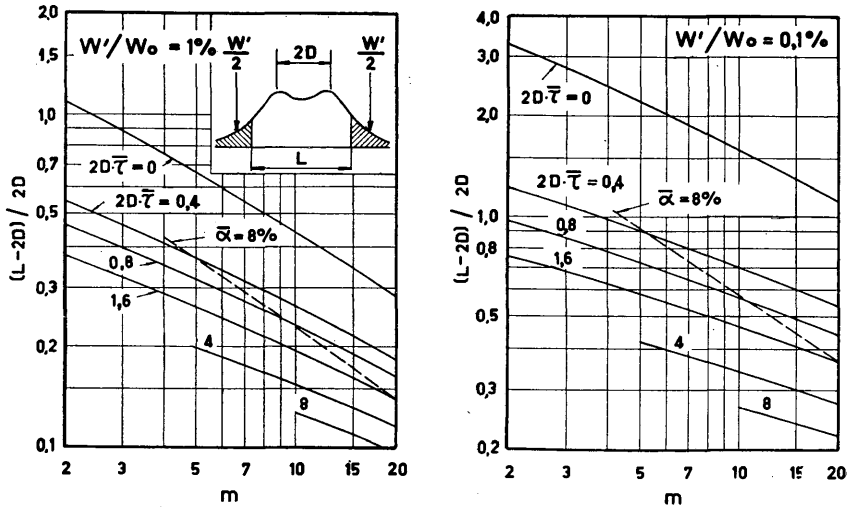


FIGURE 3

Bandwidth calculated from formula (2)

$W_o$  = total power.

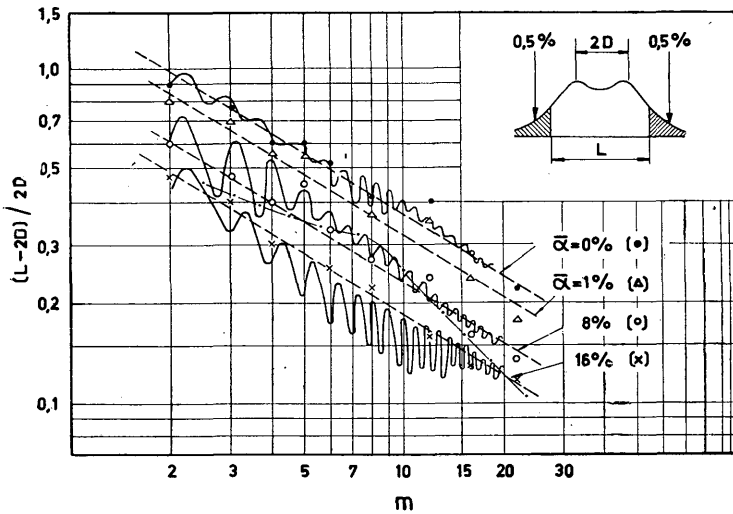


FIGURE 4

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

- · — · — · — Calculated from the formula given in Recommendation 328.
- - - - - Calculated from formula (3).
- Calculated from spectra obtained from spectrum analyzer.
- Δ ○ × Measured points obtained with the bandwidth measuring device.
- $\bar{\alpha}$  Build-up time/signal duration.

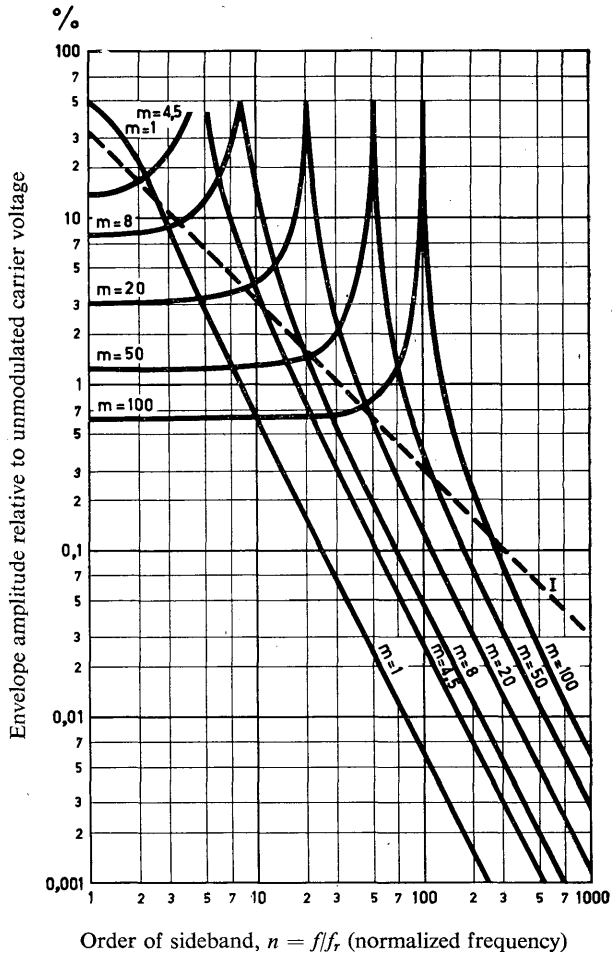


FIGURE 5

Envelopes of square-wave frequency-shift keying spectra

Curve I: A1 square-wave.

Asymptotic formula, good in linear region of curves:

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

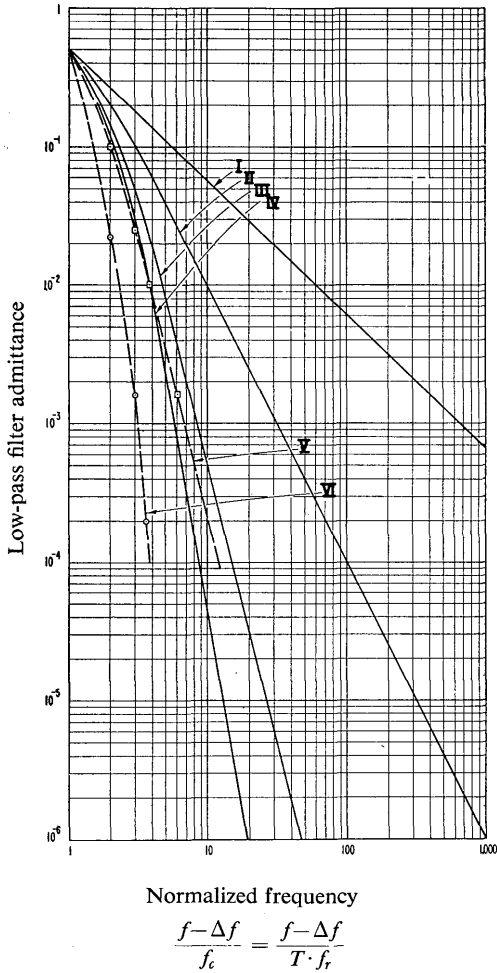


FIGURE 6

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

- Calculated curves:
- I 1 section.
  - II 2 sections.
  - III 4 sections.
  - IV 6 sections.
- Measured curves:
- V 4-section RC filter with feedback for optimum response.
  - VI 4-section LC filter with optimum transient response.

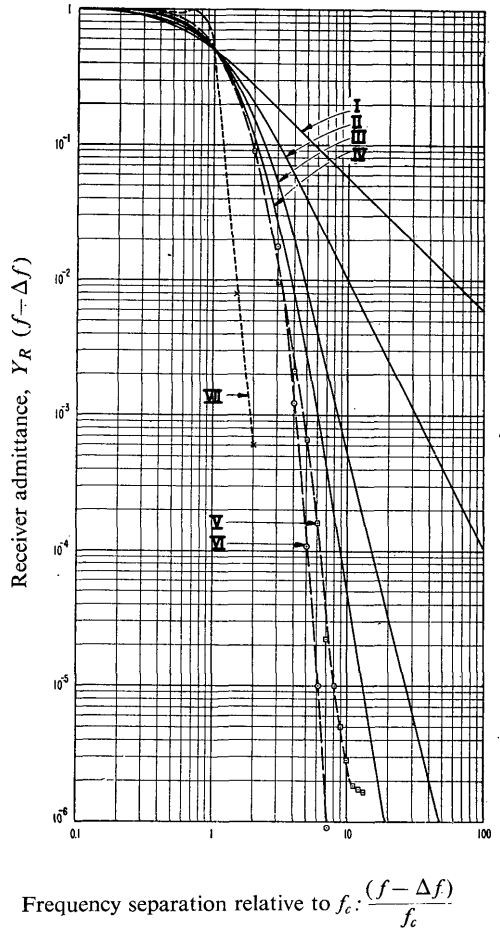


FIGURE 7

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

- Calculated curves:
- I, 1 stage; II, 2 stages; III, 4 stages; IV, 6 stages.
- Measured curves:
- V Good receiver with 4 tuned stages, i.e. two sets of coupled circuits, measured at high frequency so that 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.

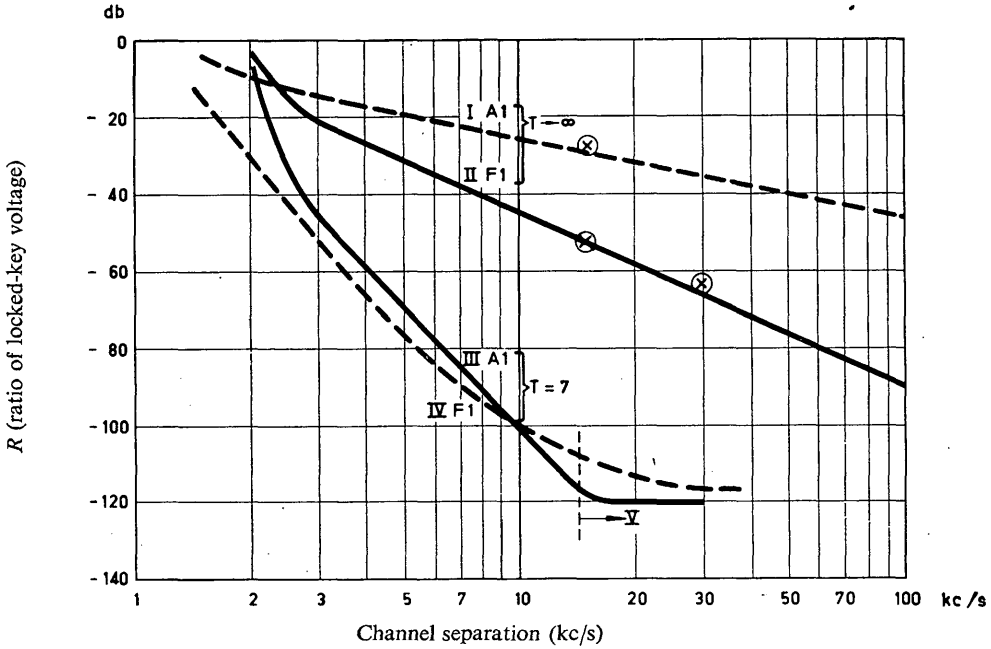


FIGURE 8

*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 kc/s (average voltage bandwidth 1.6 kc/s) with an assumed IF output ratio,  $r$ , of 2 (see § 3.3).

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

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

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

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

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

⊗ : Experimental points.

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

## REPORT 180 \*

## FREQUENCY STABILIZATION OF TRANSMITTERS

(Study Programmes 183(I) and 184(I))

(Geneva, 1963)

Contributions concerning Study Programmes 183(I) and 184(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.) of 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 of 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 183 (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. 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.

Frequency measuring equipments are available at moderate cost, with built-in frequency standards, having an accuracy of 1 part in  $10^7$  or even better. Their 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 equipments 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:

---

\* This Report was adopted unanimously.

Type of oscillator	Temperature compensation	Stability (x 10 <sup>-9</sup> )	Approximate relative price
Ordinary crystal . . . . .	no	± 100	1
Crystal with low temperature-coefficient. . . . .	no	± 20 <sup>(1)</sup>	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 <sup>(2)</sup> to 100

(<sup>1</sup>) Above 1 Mc/s only. Below 1 Mc/s, the figure is ± 50.  
 (<sup>2</sup>) The lower limit of 20 is for a single-frequency synthesizer.

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 of Geneva, 1962). The stability currently attained by such systems is ±1 part in 10<sup>8</sup>.

Attention has been drawn, however, to certain undesirable effects, which can arise in connection with the process of synthesis (Doc. I/33(Rev.) of 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 Mc/s 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 \*

## FREQUENCY TOLERANCE OF TRANSMITTERS

(Study Programme 184(I))

(Geneva, 1963)

**1. Introduction**

Study Programme 184 (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.

The attached table 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 184(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.

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

---

\* This Report was adopted unanimously.

more uniformly throughout the band, consequently reducing interference in practical operation.

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 184(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 (kc/s)	Tolerance achievable now, or in the near future (c/s)	Ultimate tolerance (c/s)
(1)	(2)	(3)	(4)
<i>Band 535-1605 kc/s</i>			
Broadcasting stations . . . . .	10	10	10
<i>Band 1605-4000 kc/s</i>			
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

Frequency bands and categories of stations	Representative value of necessary bandwidth of emission (kc/s)	Tolerance achievable now, or in the near future (c/s)	Ultimate tolerance (c/s)
(1)	(2)	(3)	(4)
<i>Band 4–29·7 Mc/s</i>			
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
A1 . . . . .	0·1	100	100
Other than A1 . . . . .	1·7	17	17
(b) Aeronautical stations: A3J . . . . .			
(c) Base stations: A3H-A3J . . . . .	3	10	10
(c) Base stations: A3H-A3J . . . . .	3	20	10
3. Mobile stations:			
(a) Ship stations: A3H-A3J . . . . .			
(b) Aircraft stations: A3J . . . . .	3	100	20
(c) Land mobile stations: A3H-A3J . . . . .	3	20	20
(c) Land mobile stations: A3H-A3J . . . . .	3	100	20
4. Broadcasting stations . . . . .	10	10	10.
<i>Band 29·7–108 Mc/s</i>			
		kc/s	kc/s
1. Land stations (50 Mc/s) . . . . .	16	1	
2. Mobile stations (50 Mc/s) . . . . .	16	1	
3. Broadcasting FM stations . . . . .	200	2	2
4. Television stations . . . . .	6000	2·5 c/s <sup>(1)</sup>	2·5 c/s <sup>(1)</sup>
<i>Band 108–470 Mc/s</i>			
		kc/s	kc/s
1. Land stations:			
(a) Coast stations (156 Mc/s) . . . . .	36	3	
(b) Base stations (470 Mc/s) . . . . .	36	2·5	0·36
2. Mobile stations:			
(a) Ship stations (156 Mc/s) . . . . .	36	3	
(b) Land mobile stations (470 Mc/s) . . . . .	36	2·5	
3. Television stations . . . . .	6000	2·5 c/s <sup>(1)</sup>	2·5 c/s <sup>(1)</sup>

<sup>(1)</sup> The tolerance of the sound channel carrier with respect to the visual carrier frequency is 1 kc/s.

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 227(I))

(Geneva, 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) of 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 ( $5 \times 10^{-10}$  s), ensure that the amplitudes of the spectral components of interfering pulses shall be constant throughout the frequency range from 0 to about 1000 Mc/s. The interference measuring set was constructed in accordance with the C.I.S.P.R. standards. (C.I.S.P.R. Publication 1, 1961. "Specification for C.I.S.P.R. radio interference measuring apparatus for the frequency range 0.15 Mc/s to 30 Mc/s").

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

- Class of emission: F1
- Total frequency shift (2 D): 200 c/s at 0.1 Mc/s  
400 c/s at other frequencies
- Telegraph signals: Reversals at 50 bauds
- Receiver type: Traffic receiver, with special telegraph equipment
- Total receiver bandwidth: 1000 c/s
- Cut-off frequency of low-pass filter: 100 c/s.

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

---

\* This Report was adopted unanimously.

TABLE I

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

Frequency of reception (Mc/s)	Pulse repetition frequency (c/s)	Level of interfering signals (db rel. 1 $\mu$ V in 60 ohms) evaluated by the interference measuring set for a wanted signal level (db rel. 1 $\mu$ V) of:				
		0	+20	+40 <sup>(1)</sup>	+60 <sup>(1)</sup>	+80 <sup>(1)</sup>
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

<sup>(1)</sup> 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) of 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.

## STUDY GROUP I

### (Emission)

#### *Terms of reference :*

1. To make specific studies and proposals in connection with radio transmitters and generally to summarize and co-ordinate proposals for the rational and economical use of the radio spectrum.
2. To study spurious radiation from medical, scientific and industrial installations.

---

*Chairman :* Colonel J. LOCHARD (France)

*Vice-Chairman :* Professor S. RYŹKO (P. R. of Poland)

---

#### INTRODUCTION BY THE CHAIRMAN, STUDY GROUP I

### 1. Spectra and bandwidths of emissions

Study Programme 181(I), Recommendation 328 and Reports 178 and 179.

The bandwidth recognized in the Radio Regulations, Geneva, 1959 (see Nos. 89 to 91 and Appendix 5) is merely a parameter of the energy spectrum of an emission, determined in accordance with an arbitrary convention. The whole of the spectrum must be known if interference is to be assessed and the frequency separation required between radio channels is to be determined.

Recommendation 328 lays down limits which may be imposed on the spectra of the most current classes of emission, with a view to economies in the use of the radio-frequency bands by reducing mutual interference between radio emissions on neighbouring frequencies.

Report 179 shows how the limits of Recommendation 328 have been achieved and verified.

Report 178 shows the main results of the theory concerning energy spectra and their limitation.

Study Programme 181(I) enumerates the many investigations still to be done to supplement the Recommendation and improve its provisions. Some theoretical bases on which such investigations might be made are given in Report 96.

### 2. Measurement of spectra and bandwidth

Study Programme 180(I), Recommendation 327 and Report 178.

For the reasons given from theory in Report 178, it is always difficult to measure the spectra and bandwidths necessary, if the limitations mentioned above are to be applied and to assess interference.

Recommendation 327 describes various possible methods of measurement and the characteristics and accuracy of the various types of equipment.

Study Programme 180(I) summarizes the studies still to be undertaken to improve the methods of measurement.

### 3. Spurious emissions

Study Programme 182(I) and Recommendation 329.

Appendix 4 to the Radio Regulations, Geneva, 1959, limits the spurious radiation of emissions at fundamental frequencies below 235 Mc/s. Recommendation 329 shows what

limitations can be imposed on emissions between 235 and 960 Mc/s and describes the various possible methods of measurement.

Study Programme 182(I) indicates investigations still to be undertaken.

#### **4. Compression of the spectra of HF radiotelegraph and radiotelephone signals**

Questions 219(I) and 220(I) and Reports 176 and 177.

While limitation of spectra and reduction of spurious emissions can be almost entirely achieved by linear filtering operations, the degree of compression here envisaged is feasible only if more complicated non-linear operations be undertaken.

Reports 176 and 177 describe systems already evolved and explain why they are difficult to apply under the conditions of propagation met with in the HF bands.

Certain investigations still to be undertaken are mentioned.

#### **5. Limitation of radio-frequency emissions from industrial, scientific and medical equipment and other kinds of electrical equipment**

Question 227(I), Study Programmes 227A(I), 227B(I) and 227C(I), Opinion 2 and Report 182.

The limitation of interference caused to radiocommunications by electrical equipment makes national regulations, imposed on manufacturers and users of electrical equipment necessary. In consequence, the C.C.I.R. decided to study the technical bases of such regulations, in cooperation with the C.I.S.P.R., a body organized by the International Electro-technical Commission.

The above texts enumerate the investigations to be undertaken, describe how such cooperation is organized and give some idea of the results obtained up to the present.

#### **6. Stabilization of the frequencies and frequency tolerances of radio transmitters**

Study Programmes 183(I) and 184(I), and Reports 180 and 181.

Appendix 3 to the Radio Regulations, Geneva, 1959, lays down frequency tolerances for most of the categories of station.

Report 181 describes the extent to which restriction of these tolerances will, in future, be desirable and feasible, in accordance with Study Programme 184 (I).

Report 180 summarizes the results obtained with various methods of stabilization.

Study Programme 183(I) lists investigations still to be undertaken in this field.

#### **7. Power of radio transmitters**

Recommendation 326.

This Recommendation is chiefly concerned with standardization of procedures for determining the various values of power of radio transmitters, as defined by the Radio Regulations, Geneva, 1959 (Nos. 94, 95, 96 and 97), and to indicate the relationships between these values, which often depend on the signal transmitted, the distortion permitted, and the method of measurement, and an attempt is made to standardize these variables.

#### **8. Classification and designation of emissions**

Question 207(I), Recommendation 325, Report 175 and Opinion 1.

Recommendation 325 proposes the definitions requested by the Administrative Radio Conference, Geneva, 1959.

Report 175 proposes a new code for designation of emissions, designed to meet the requirements of the I.F.R.B. in drawing up the International Frequency List and Master International Frequency Register. The code now in force (Article 2 of the Radio Regulations, Geneva, 1959) is no longer sufficient for the unambiguous designation of the classes of emission more recently introduced.

Opinion 1 indicates a procedure, and enumerates investigations to be undertaken, with a view to improving the system proposed.

QUESTION 207(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;
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

**CLASSIFICATION AND DESIGNATION OF EMISSIONS**

(Question 207(I))

(Geneva, 1963)

The C.C.I.R.,

CONSIDERING

- (a) that studies of the contributions related to Question 207 (I), from Administrations and the I.F.R.B., have been made;
- (b) that, as a result of this study, Report 175 proposes a new method for the classification and designation of emissions;
- (c) that, until the effectiveness of this new method has been established, it should not be included in a Recommendation;
- (d) that it may be possible to introduce improvements into the proposed method;

IS UNANIMOUSLY OF THE OPINION that the I.F.R.B. should be invited:

1. to organize necessary trials, in cooperation with Administrations, to ascertain the effectiveness of the method for the classification and designation of emissions proposed in Report 175;
2. to collect all relevant information obtained during these trials, to permit a comprehensive assessment of the effectiveness of the proposed method;
3. to present a definite and detailed Recommendation, for consideration at the XIth Plenary Assembly of the C.C.I.R., indicating all improvements to the proposed method that may be considered advisable.

---

QUESTION 219(I)

**COMPRESSION OF THE RADIOTELEPHONE SIGNAL SPECTRUM  
IN THE HF BANDS**

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 Mc/s;

---

\* In collaboration with Study Group XIV.

- (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 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 220(I)

#### COMPRESSION OF THE RADIOTELEGRAPH SIGNAL SPECTRUM IN THE HF BANDS

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 Mc/s;
- (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.:

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?
-

## STUDY PROGRAMME 180(I) \*

## METHODS OF MEASURING EMITTED SPECTRA IN ACTUAL TRAFFIC

The C.C.I.R.,

(London, 1953 – Geneva, 1963)

## 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 telegraph speed;
2. comparison of the results obtained with different methods, such as those described in Recommendation 327;
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.

## STUDY PROGRAMME 181(I) \*\*

## SPECTRA AND BANDWIDTHS OF EMISSIONS

The C.C.I.R.,

(Geneva, 1951 – London, 1953 – Warsaw, 1956 –  
Los Angeles, 1959 – Geneva, 1963)

## CONSIDERING

- (a) that Appendix 5 of the Radio Regulations, Geneva, 1959 and Recommendation 328, deal with only a limited number of classes of emission, and that they were established on the basis both of theoretical considerations and of measurements, made in conditions not always representative of those encountered in actual traffic;
- (b) that it is, therefore, necessary to extend the theoretical and experimental study of spectra for the various classes of emission;
- (c) 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;

---

\* This Study Programme, which replaces Study Programme 40, does not arise from any Question under study.

\*\* This Study Programme, which replaces Study Programme 126, does not arise from any Question under study.

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;
2. continuation of studies of bandwidths and spectra, under actual traffic conditions in the different cases met with in practice, for all classes of emissions, in accordance with the following provisions:
  - 2.1 the studies should be carried out simultaneously by theoretical and experimental methods, and a detailed comparison should be made of the results obtained by both methods. The experimental studies should make use of the methods of measurement set out in Recommendation 327, as well as methods of measurement in actual traffic, which might be developed along the lines of Study Programme 180 (I);
  - 2.2 the studies should be carried out 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;
  - 2.3 the studies should be conducted for the various classes of emission, along the following lines and applying to different types of transmitters in service or under development:

#### 2.3.1 *Class A1, A2 and F1 emissions*

A sufficiently large number of measurements of spectra and of signal shape should be carried out on different types of transmitters at present in use.

The appropriate means for limiting the spectra of these transmitters, as well as of new transmitters to be constructed, should be studied, with the aim, on the one hand, of determining the requisite filters and, on the other hand, of achieving a sufficient linearity of the amplifying stages or of the frequency modulators.

The transmitters so improved should be put into service, so that final conclusions on their performance may be established for various operating conditions.

These studies should, in particular, be made in the frequency range of 10 kc/s to 30 000 kc/s for the following classes of emissions:

##### 2.3.1.1 *Telegraphy A1, A2, A7A, A7B, F1*

- automatic Morse;
- teleprinter and other automatic telegraph equipment, working at 50 and 120 bauds;
- error-detecting and error-correcting systems, working at 171 3/7, 192 and 200 bauds with various numbers of channels, and multiplexing arrangements;
- the “Hellschreiber” system;
- F1 telegraphy systems, with various frequency shifts, in particular of the order of 200 to 800 c/s, with modulation indices between about 0.5 and 20;

##### 2.3.1.2 *Telegraphy F6*

- with various values of frequency shifts, possibly higher than those quoted above.

#### 2.3.2 *Class A3, A3A, A3B, A3H and A3J emissions*

Measurements of radiation outside the necessary band should be made with transmitters of different types, using this class of emission, and in particular with independent-sideband transmitters.

These measurements should be made with narrow bandwidth measuring apparatus, such as described in Recommendation 327, and the results should be compared with those obtained with wide-band apparatus, as mentioned in Recommendation 328, § 2.4.

It would be useful to perform these measurements when the transmitter is modulated by an artificial voice or by white noise; these two modulations approximately reproducing the two practical cases where the transmitter is used without privacy equipment, or with a band-splitting privacy device.

Methods for still further reducing out-of-band radiation should be investigated.

These studies should, in particular, be made in the frequency range of 10 kc/s to 30 000 kc/s for the following classes of emissions:

2.3.2.1 *Telephony*, double-sideband, full carrier (A3):

- low grade;
- commercial quality, with privacy equipment;
- broadcasting quality.

2.3.2.2 *Telephony*, single- and independent-sideband systems with reduced or suppressed carriers, one to four channels, commercial quality, with or without privacy equipment.

2.3.3 *Other classes of emission*

Comparative studies should be undertaken for the other classes of emission used in international telecommunications, in particular for those used in the HF (decametric) band such as:

2.3.3.1 *Facsimile A4 and F4*, with direct modulation of the main carrier, or of a sub-carrier, by the picture signal.

2.3.3.2 *Independent-sideband systems*, used simultaneously for telephony and for voice-frequency telegraphy, facsimile etc.

These studies should then be extended to the classes of emission used in the VHF (metric), UHF (decimetric) and SHF (centimetric) bands;

- 2.4 other studies based on new principles should be undertaken as suggested in Report 178, with a view to their possible application to new equipments;
- 2.4.1 the reduction of out-of-band radiation could be obtained through the determination of the best statistical distribution of the signal amplitudes, which would permit a sufficient filtering of the signal without undue distortion, and the determination of the practical coding processes to produce such a statistical distribution;
- 2.4.2 to reduce the occupied bandwidth, the most favourable shape of a practical elementary signal should be sought theoretically and the practical shaping circuits to produce such a shape should be developed;
- 2.4.3 the filtering and coding of the signal envisaged in the two preceding studies will introduce a delay, which may be justified if a reduction of interference is obtained. The maximum acceptable delay should be determined for the various classes of emission and different services and taken into account in assessing the number of filter sections to be used;
- 2.5 the studies of the concepts of necessary and occupied bandwidth should be continued, with a view to obtaining definitions which will facilitate both measurement and theoretical determination of these quantities;
- 2.5.1 percentages of power, differing from the value of 99% which has proved useful for some classes of emission, should be sought for classes of emission of more recent use, such as frequency-division multiplex with a large number of channels, especially those designed for microwave systems;
- 2.5.2 the level of the spectrum components near the limits of the occupied band should be studied, both theoretically and experimentally, for the different classes of emission, to facilitate evaluation of occupied bandwidths from level measurements of spectrum components (see Doc. 119 (U.S.S.R.) of Los Angeles, 1959).

STUDY PROGRAMME 182(I) \*

SPURIOUS RADIATION (OF AN EMISSION)

The C.C.I.R.,

(Geneva, 1951 – Los Angeles, 1959 – Geneva, 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 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 equipments;
- (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, 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;

\* This Study Programme, which replaces Study Programme 124, does not arise from any Question under study.

2. secure further data on the methods of measurement of spurious radiations, in particular, on the measurement of such radiations produced as 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 183(I) \*

#### FREQUENCY STABILIZATION OF TRANSMITTERS

The C.C.I.R.,

(Geneva, 1951 – Los Angeles, 1959 – Geneva, 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 analyze 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.

---

\* This Study Programme, which replaces Study Programme 125, does not arise from any Question under study.

STUDY PROGRAMME 184(I) \*

FREQUENCY TOLERANCE OF TRANSMITTERS

The C.C.I.R.,

(Geneva, 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 the 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.

---

\* This Study Programme, which replaces Study Programme 169 (Recommendation No. 1 of the Administrative Radio Conference, Geneva, 1959), does not arise from any Question under study.

## QUESTION 227(I) \*

**LIMITATION OF RADIATION FROM INDUSTRIAL, SCIENTIFIC  
AND MEDICAL INSTALLATIONS AND OTHER KINDS  
OF ELECTRICAL EQUIPMENT**

The C.C.I.R.,

(London, 1953 – Geneva, 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 radiations from industrial, scientific and medical installations and other kinds of electrical equipment, 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 industrial, scientific or medical installations and other kind of electrical equipment;
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.

---

\* This Question replaces Question 75.

STUDY PROGRAMME 227A(I) \*

LIMITATION OF UNWANTED RADIATION  
FROM INDUSTRIAL INSTALLATIONS

The C.C.I.R.,

(Warsaw, 1956)

CONSIDERING

- (a) that no standard measuring method can yet be recommended for the measurement of unwanted radiation;
- (b) that the effect of interference is dependent on the particular type of service and on the waveform of the unwanted radiation;
- (c) that, it is desirable to compare measurements made at various test sites and possibly using different methods;
- (d) that the effect of interference depends on the transmission coefficient between the source of interference and the receiver affected;
- (e) that the C.I.S.P.R. has already studied, and continues to study, extensively the measuring methods for determining the level of interference from industrial, scientific and medical apparatus to sound and television broadcasting;
- (f) 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. The polarization and the relation between the magnetic and electric field should be considered;
2. the effects of the relative positions of the industrial, scientific and medical equipment; or groups of equipments, and the measuring set, the number of measurements at different distances and the number of directions in which measurements should be made;
3. the effect of different open sites on the measured field;
4. the methods that can be used to measure the radiation from industrial, scientific and medical equipment which is situated indoors and the relationship between measurements made indoors and those made on outside sites;
5. the importance of interference due to the presence of radio-frequency voltages in the mains leads of the industrial, scientific and medical equipment and the methods of measurement;
6. the effect of the working conditions of the apparatus to be measured during the measurements;
7. the wave collectors to be used for measurements in the different frequency bands;
8. the characteristics of the equipment to be used for the measurements, particularly its bandwidth;
9. the way in which interference with various radio services depends upon the waveform of the disturbing field;
10. the statistical distribution and the representative values for the transmission coefficient between the interference sources and the receiving antenna in the service concerned.

*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.

---

\* This Study Programme was formerly designated Study Programme 84 (I).

## STUDY PROGRAMME 227B(I)

EXAMINATION OF RESULTS OBTAINED BY THE INTERNATIONAL  
SPECIAL COMMITTEE ON RADIO INTERFERENCE

The C.C.I.R.,

(Geneva, 1963)

## CONSIDERING

- (a) that, since its last Plenary Assembly in Philadelphia (1961), 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. the use by Administrations of the measurement methods and equipment described in C.I.S.P.R. Publications 1 and 2 (1961), and their supplements (see [1] to [5]);
2. with these methods and apparatus, to take measurements 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. Recommendations (see [6] to [10]);
3. to make measurements in the vicinity of radio-receiving installations suffering from interference, and to determine the sources of disturbance and their characteristics;
4. 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;
5. 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;
6. 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.

## 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.
2. C.I.S.P.R. Publication 2 (1961). – Specification of apparatus for measuring radio interference in the range from 25 to 300 Mc/s.
3. C.C.I.R. Doc. 134 of Geneva, 1963. – (This document reproduces those supplements to 1. and 2. which have been issued up to the present.)
4. I.E.C. Publication 106, 1st Edition (1959). – Recommended methods of measurement of radiation from receivers for amplitude-modulation, frequency-modulation and television broadcast transmission.
5. I.E.C. Publication 106A (1962).
  - (a) Measurement of radiation at the intermediate frequency and its harmonics in the range 30 to 300 Mc/s.
  - (b) Extension of the general methods of measurements of radiation in the range 300 to 1000 Mc/s.
6. C.I.S.P.R. Recommendation 16. – Limits of interference for large industrial radio-frequency equipment which cannot be measured on a test site.

7. C.I.S.P.R. Recommendation 17. – Limits of interference from medical diathermy equipment and equipment producing broadband interference other than RF-excited arc welders.
8. C.I.S.P.R. Recommendation 18. – Interference from ignition systems.
9. C.I.S.P.R. Recommendation 21. – Evaluation of interference at low repetition frequencies.
10. C.I.S.P.R. Recommendation 24. – Limits for radiation from sound and television broadcast receivers.

---

STUDY PROGRAMME 227C(I)

**PROTECTION OF RADIOCOMMUNICATION EQUIPMENT FROM  
INTERFERENCE BY INDUSTRIAL, SCIENTIFIC AND MEDICAL  
INSTALLATIONS AND OTHER KINDS OF ELECTRICAL EQUIPMENT**

The C.C.I.R.,

(Geneva, 1963)

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 industrial, scientific and medical installations and other kinds of electrical equipment;
- (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 other Study Groups, notably II, III, VI, X and XI;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. to examine the relevant conclusions of Study Groups II, III, VI, X and XI concerning signal-to-noise ratios, signal-to-interference ratios, minimum field-strengths required and levels of natural noise, reached at the Xth Plenary Assembly, Geneva, 1963;
  2. to determine the values of the minimum field to be protected and the maximum tolerable interference for each service and type of interference, in so far as the necessary information is available;
  3. to specify the way in which the field and interference should be measured in each case;
  4. to 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.,

(Geneva, 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 industrial, scientific and medical installations and other kinds of electrical equipment, such as ignition systems of internal combustion engines, electric motors, switches, fluorescent lighting apparatus, etc. (Question 227(I); Study Programme 227A(I));
  - 1.2 all types of receivers (Recommendation 239; Question 176(II); Publications 106 and 106A of the International Electrotechnical Commission);
2. determination of the maximum interference level tolerable in complete systems (Question 227(I));
3. identification of sources of interference with radio reception (Question 257(VIII));
4. study of the usable sensitivity of receivers in the presence of quasi-impulsive interference (Question 175(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 153(VI)).

---

\* The Opinion replaces Recommendation 27 and Resolution 39.

LIST OF DOCUMENTS OF THE Xth PLENARY ASSEMBLY CONCERNING STUDY GROUP I

Doc.	Origin	Title	Reference	Other Study Groups concerned
1	Chairman, Study Group I	Report by Chairman of Study Group I (Col. J. Lochard)	—	—
22	United States of America	Frequency tolerance of transmitters	S. P. 169	—
23	United States of America	Draft amendment to Recommendation 228 – Definition of the characteristics of a single-sideband emission	Rec. 228	—
44	United Kingdom	Classification and designation of types of emission – Draft Report	Q. 207	—
63	C.I.R.M.	Frequency tolerances of marine transmitters	S. P. 169	—
64	United Kingdom	Definition of « emission », « radiation » and « transmission »	Q. 207, § 4	—
77	C.C.I.R. Secretariat	Frequency tolerance of transmitters	Circ. AC/60	—
78	C.C.I.R. Secretariat	Extension of the tolerances for spurious radiation fixed by Appendix 4 of the Radio Regulations to fundamental frequencies above 235 Mc/s	Circ. AC/60	—
86	C.C.I.R. Secretariat	Power of emissions	Circ. G.1/204 and 207	—
129	C.C.I.R. Secretariat	Bibliographic references in the Volumes of the C.C.I.R.	—	I–XIV
134	C.I.S.P.R.	Modifications to C.I.S.P.R. Publications 1 and 2	Q. 75	—
144	Switzerland	Unwanted radiation from industrial, scientific and medical (ISM) installations – Typical values for ISM installations	Q. 75	—
153	C.C.I.R. Secretariat	Refinement of I.F.R.B. technical standards	—	II, III, V, VI, X, XII, XIII
301	Study Group I	Summary record of the first meeting	—	—
316	Working Group I-D	Classification and designation of emissions	Q. 207	—
317	Study Group I	Measurement of spectra and bandwidths of emissions	Rec.	—
318	Study Group I	Addition to Report 96 – Possibilities of reducing interference and of measuring actual traffic spectra	Q. 133 S. P. (Ann. 1/8)	—
319	Study Group I	Addition to Report 97 – Bandwidth of A1 and F1 telegraphic emissions – Evaluation of interference produced by these emissions	S. P. (Ann. 1/8)	—
345	Study Group I	Summary record of the second meeting	—	—
358	Sub-Group I-B	Cooperation with the international special committee on radio interference	Draft Op.	—
359	Sub-Group I-B	Determination of the maximum level of interference caused by industrial, scientific and medical installations and other kinds of electrical equipment tolerable in complete radio systems	Draft Rep. Q. (Ann. 1/9)	—

Doc.	Origin	Title	Reference	Other Study Groups concerned
360	Sub-Group I-B	Limitation of radiation from industrial, scientific and medical installations and other kinds of electrical equipment	Draft Q.	—
394	Sub-Group I-D	Classification and designation of emissions	Draft Op. Q. 207	—
395	Study Groups I and XIV	Draft Recommendation	Q. 207, § 4	XIV
405	Study Group I	Summary record of the third meeting	—	—
430	Sub-Group I-B	Spurious radiation	Draft S. P.	—
431	Sub-Group I-B	Protection of radiocommunication equipment from interference by industrial, scientific and medical installations and other kinds of electrical equipment	Draft S. P. Q. (Ann. 1/9)	—
433	Sub-Group I-C	Frequency stabilization of transmitters	Draft Rep.	—
469	Sub-Group I-B	Examination of results obtained by the international special committee on radio interference	Draft S. P.	—
471	Sub-Group I-C	Frequency tolerance of transmitters	Draft Rev. of S. P. 169	—
472	Sub-Group I-C	Frequency stabilization of transmitters	Draft Rev. of S. P. 125	—
477	Sub-Group I-C	Compression of the radiotelephone signal spectrum in the HF bands	Draft Rep.	—
478	Sub-Group I-C	Compression of the radiotelegraph signal spectrum in the HF bands	Draft Rep.	—
521	Sub-Group I-E	Power of radio transmitters	Draft Rec.	—
545	Sub-Group I-C	Frequency tolerance of transmitters	S. P. 169	—
570	Sub-Group I-B	Spurious radiation (of a radio emission)	Draft Rec.	—
595	Study Group I	Summary record of the fourth and last meeting	—	—
2065	Drafting Committee	Spectra and bandwidths of emissions	Rec. 328	—
2066	„ „	Methods of measuring emitted spectra in actual traffic	S. P. 180	—
2067	„ „	Spectra and bandwidths of emissions	S. P. 181	—
2068	„ „	Measurement of spectra and bandwidths of emissions	Rec. 327	—
2069	„ „	Possibilities of reducing interference and of measuring actual traffic spectra	Rep. 178	—
2070	„ „	Bandwidth of A1 and F1 telegraphic emissions - Evaluation of interference produced by these emissions	Rep. 179	—
2109	„ „	Classification and designation of emissions	Rep. 175	—
2110	„ „	Cooperation with the international special committee on radio interference	Res. 2	—

Doc.	Origin	Title	Reference	Other Study Groups concerned
2111	Drafting Committee	Determination of the maximum level of interference caused by industrial, scientific and medical installations and other kinds of electrical equipment that is tolerable in complete radio systems	Rep. 182	—
2112	„ „	Limitation of radiation from industrial, scientific and medical installations and other kinds of electrical equipment	Q. 227	—
2113	„ „	Classification and designation of emissions	Res. 1	—
2256	„ „	Power of radio transmitters	Rec. 326	—
2257	„ „	Terminology	Rec. 325	XIV
2258	„ „	Examination of results obtained by the international special committee on radio interference	S. P. 227B	—
2261	„ „	Spurious radiation (of an emission)	S. P. 182	—
2266	„ „	Protection of radiocommunication equipment from interference by industrial, scientific and medical installations and other kinds of electrical equipment	S. P. 227C	—
2267	„ „	Frequency stabilization of transmitters	Rep. 180	—
2268	„ „	Frequency tolerance of transmitters	S. P. 184	—
2269	„ „	Frequency stabilization of transmitters	S. P. 183	—
2270	„ „	Compression of the radiotelephone signal spectrum in the high frequency bands	Rep. 176	—
2271	„ „	Compression of the radiotelegraph signal spectrum in the high frequency bands	Rep. 177	—
2272	„ „	Frequency tolerance of transmitters	Rep. 181	—
2311	„ „	Spurious radiation (of a radio emissions)	Rec. 329	—

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

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.,

(Warsaw, 1956 – Los Angeles, 1959)

CONSIDERING

- (a) that Recommendation 331 gives general recommendations on receiver sensitivity;
- (b) that Recommendation 332 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 176 (II))

The C.C.I.R.,

(Warsaw, 1956 – Los Angeles, 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;

---

\* This Recommendation, together with Recommendation 330, replaces Recommendations 157 and 158.

\*\* Available from the Central Office of the I.E.C. in 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 of 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 \* on the methods of measuring spurious emissions from broadcast and television receivers up to 300 Mc/s, while an extension of the band up to 1000 Mc/s 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 of Warsaw, 1956, and 107 of 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.,

(Warsaw, 1956 – Los Angeles, 1959 – Geneva, 1963)

## CONSIDERING

- (a) that Recommendation 331 gives general recommendations on receiver sensitivity;
- (b) that Recommendation 332 gives general recommendations on receiver selectivity;

\* Publication 106 of the I.E.C.

\*\* J. MEYER DE STADELHOFEN. *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.\*\*\* C. EGIDI. *Confronto di apparecchiature normalizzate per la misura delle irradiazioni parassite* - Elettronica, 1956.

\*\*\*\* This Recommendation replaces Recommendation 238.

- (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 measurement methods 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 measurement methods from time to time should be used as a guide by the C.C.I.R.

---

RECOMMENDATION 331 \*\*

NOISE AND SENSITIVITY OF RECEIVERS

The C.C.I.R., (Geneva, 1951 – London, 1953 – Warsaw, 1956 –  
Los Angeles, 1959 – Geneva, 1963)

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);
- (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);
- (f) that Question 228 (II) asks for additional data on noise factor and sensitivity for the various types of receivers used for reception of different classes of emission in the different services;

---

\* Available from the Central Office of the I.E.C., Geneva.

\*\* This Recommendation replaces Recommendation 234.

- (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 receivers 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 theoretically possible;
- (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 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 \*;
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;
 

<ol style="list-style-type: none"> <li>4.1 – the signal level</li> <li style="padding-left: 20px;">or</li> <li>4.2 – the signal-to-noise ratio</li> </ol>	}	necessary for normal operation
---	---	--------------------------------

when the normal degree of modulation \*\*\* is applied to the carrier. If the gain is sufficient

\* See Doc. 3 of Geneva, 1951.

\*\* For frequencies above about 30 Mc/s the input signal strength is usually taken as the available power from the source.

\*\*\* Class A1 modulation is considered 100% modulated.

o 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 uncertainty 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 \*;

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;

9.4 \*\*\* for the purpose of comparing and presenting data 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 transmissions;
- the source impedance (dummy antenna);

\* See Recommendation 332.

\*\* See Doc. 227 of Warsaw, 1956, Doc. II/3, II/11 and II/23 of Geneva, 1958.

\*\*\* See Annex II, § 5.

- 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 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);
12. 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 of Geneva, 1962. The data were collected as part of the studies required by Question 228 (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      }      fixed service F1      }	{ 30 - 600 kc/s 1 600 - 30 000 kc/s 30 - 300 Mc/s
2. Telephony A3      { fixed service general purpose mobile service A3B      fixed service } F3      { fixed service general purpose mobile service	{ 30 - 600 kc/s 1 600 - 30 000 kc/s 30 - 300 Mc/s
3. Sound broadcasting A3 F3	{ 150 - 300 kc/s 500 - 1 600 kc/s 1 600 - 30 000 kc/s { 30 - 100 Mc/s 100 - 300 Mc/s 300 - 1 000 Mc/s
4. Television A5      Vision A3      } F3      }      Sound	{ 30 - 100 Mc/s 100 - 300 Mc/s 300 - 1 000 Mc/s

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)

$$E^2 = 8 kT (BRn/m^2) F \times 10^{12} \tag{1}$$

where:

$E$  : e.m.f. of the carrier ( $\mu V$ ) 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 constant =  $1.37 \times 10^{-23}$  (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 (c/s), 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)

$$E^2 = 4 kTB R n F \times 10^{12} \quad (2)$$

where:

$E$  : e.m.f. of the sideband component ( $\mu$ V) 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 (c/s), 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)

$$E^2 = 8 kT (BRn/q^2) F \times 10^{12} \quad (3)$$

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 \***

- 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 c/s, 200 c/s and 100 c/s; 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, §§ 2.1, 2.2 and 2.5;  
 Recommendation 338, §§ 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 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 \*\***

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 
$$E^2 : 4 kTR \cdot 10^{12} \cdot F \cdot n_c \cdot S$$

If  $R = 75 \Omega$

$$E^2 = C_1 \cdot F \cdot n_c \cdot S$$

$C_1$  : –59.2 db

6.3 
$$E^2 = C_2 \cdot F \cdot n_c$$

$C_2$  : –42.2 db for 50 bauds

: –39.2 for 100 bauds.

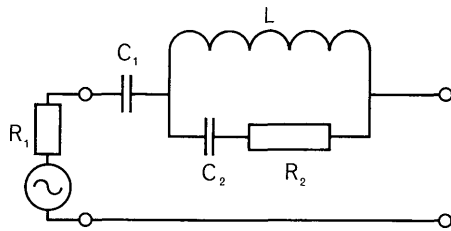
\* See Doc. 227 of Warsaw 1956, Doc. II/3, II/11, II/21 and II/23 of Geneva, 1958.  
 \*\* See Report 195.

TABLE I

Typical reference values for parameters used in calculating and measuring reference sensitivity

Class of emission	Service	Effective overall noise band $B$ (c/s)	Source resistance $R$ $\Omega$	Output-signal-to-noise power ratio $n$ (db)	Degree of modulation $m$ (c/s)	Peak system deviation for F3 (kc/s)	$10 \log C$ (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 <sup>(1)</sup> - 6.2 <sup>(2)</sup>	
	Mobile	1000	75	20	0.3		+4.3 <sup>(1)</sup> - 6.2 <sup>(2)</sup>	
A3	Fixed General purpose Mobile	3000	75	20	0.3		+9.1	
	Sound-broadcast (MF) domestic use	5000	dummy antenna <sup>(3)</sup>	20	0.3			
	Sound broadcast (HF)	domestic use	5000	dummy antenna <sup>(3)</sup>	20	0.3		+18.3
		professional use	5000	75	20	0.3		+11.1
A3B	Fixed	3000	75	20			-4.4	
F3	Fixed General purpose Mobile	3000	75	20	$0.3 \pm 4.5^{(5)}$	$\pm 15$	-9.7	
	Sound-broadcasting	5000	75	20 <sup>(4)</sup>	$0.3 \pm 22.5^{(5)}$	$\pm 75$	-17.0	
		5000	75	40	$0.3 \pm 22.5^{(5)}$	$\pm 75$	+3	
		5000	75	20 <sup>(4)</sup>	$0.3 \pm 15^{(5)}$	$\pm 50$	-13.8	
				40	$0.3 \pm 15^{(5)}$	$\pm 50$	+6.2	
		5000	300	20 <sup>(4)</sup>	$0.3 \pm 15^{(5)}$	$\pm 50$	-7.8	
40	$0.3 \pm 15^{(5)}$	$\pm 50$	+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 kc/s - sound broadcasting 75 and 50 kc/s).



- $C_1 = 125 \text{ pF}$
- $C_2 = 400 \text{ pF}$
- $L = 20 \text{ } \mu\text{H}$
- $R_1 = 80 \text{ } \Omega$
- $R_2 = 320 \text{ } \Omega$
- $Q_L > 15$  (to 1 Mc/s)

FIGURE 1 - Dummy Antenna

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.

Representative values of noise factor for good modern receivers, which are especially designed to have low noise factors, are given in Table II\*:

TABLE II

Frequency (Mc/s)	Noise factor	
	Power ratio	db
up to 100	2.5	4.0
200	3.5	5.4
500	5.5	7.4
1 000	8.0	9.0
2 000	11.2	10.5
5 000	18.0	12.5
10 000	25.0	14.0

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 Mc/s) (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 receivers. 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

\* Slightly better results have been obtained with special radioastronomic receivers (see for example Doc. 105 (India) of Geneva 1963); with molecular and parametric amplifiers much better results can be obtained.

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)<sup>(1)</sup>

Class of emission	Service	Frequency range (Mc/s)		Reference sensitivity (db rel. to 1 $\mu$ V)	Noise factor (db)	Reference bandwidth (c/s)	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

<sup>(1)</sup> See Annex IV to Recommendation 154 (Warsaw, 1956).

TABLE IV  
Reference sensitivity and noise factor for radiotelephony receivers<sup>(1)</sup>

Class of emission	Service	Frequency range (Mc/s)		Reference sensitivity (db rel. to 1 $\mu$ V)	Noise factor (db)	Reference bandwidth (c/s)	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 Mc/s
	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 Mc/s
	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 Mc/s
	Mobile <sup>(2)</sup>	30-300	Max. Mean Min.	+ 7.3 + 0.8 - 3.7	17 10.5 6	3000	Many receivers tested Freq. range = 60-200 Mc/s

<sup>(1)</sup> See Annex IV of Recommendation 154 (Warsaw, 1956) and Doc. II/32 of Geneva, 1958.

<sup>(2)</sup> See also Doc. 445 of Warsaw, 1956.

TABLE V  
Reference sensitivity and noise factor for sound-broadcast receivers<sup>(1)</sup>

Class of emission	Service	Frequency range (Mc/s)		Reference sensitivity (db rel. to 1 $\mu$ V)	Noise factor (db)	Reference bandwidth (c/s)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A3	Sound broadcasting	500-1600 kc/s	Mean	+35.5		5000	Mass-produced receivers <sup>(2)</sup> Standard deviation = 3.5 db Source impedance = dummy antenna
		1600-30 000 kc/s	Mean	+38.7	20.4	5000	Mass-produced receivers <sup>(2)</sup> Source impedance = dummy antenna (400 ohms)
		1600-30 000 kc/s	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 Mc/s	Mean	+19.1	8	5000	

<sup>(1)</sup> See Annex IV to Recommendation 154 (Warsaw, 1956).

<sup>(2)</sup> See Doc. 398 of 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<sup>(1)</sup>

*Noise factor of A1 and F1 receivers for the fixed services*

Class of emission	Service	Frequency range (Mc/s)		Noise factor (db)
(1)	(2)	(3)	(4)	(5)
A1 } F1 }	Fixed	1.6–30	Max. Mean Min.	10 7 4

<sup>(1)</sup> See Annex IV of Recommendation 154 (Warsaw, 1956) and Docs. II/3, II/21 and II/32 of Geneva, 1958.

TABLE VII

*Sensitivity of radiotelegraph receivers (automatic reception) (A1)<sup>(1)</sup>*  
 (Signal distortion and signal mutilation)

Class of emission	Frequency range (Mc/s)	Frequency shift (c/s)	Keying speed (bauds)	Filter bandwidth (c/s)		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. to 1 $\mu$ V)	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

<sup>(1)</sup> Calculated from data given in Doc. II/21 of Geneva, 1958, according to Annex II, § 6.

TABLE VIII

Sensitivity of radiotelegraph receivers (automatic reception) (F1)<sup>(1)</sup>

(Signal distortion and signal mutilation, i.e. element error-rate)

Class of emission	Frequency range (Mc/s)	Frequency shift (c/s)	Keying speed (bauds)	Filter bandwidth (c/s)		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. to 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		
			1000	120	D	14.2	7	-18		
		100	1000	250	D	17.7	7	-14.5		
			1000	75	M	16.7	7	-18.5		
		200	50	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
		200 400 800	50	300 600 1400	100	D		8.5		
									200 400 800	171 3/7

Source impedance = 75 ohms

(<sup>1</sup>) Calculated from data given in Docs. II/3 and II/21 of Geneva, 1958 and Doc. II/3 of Geneva, 1962, according to Annex II, § 6.

TABLE IX

*Sensitivity of radiotelegraph receivers (automatic reception) (F1)<sup>(1)</sup>*  
(Character error-rate)

Class of emission	Frequency range (Mc/s)	Frequency shift (c/s)	Keying speed (bauds)	Filter bandwidth (c/s)			Normalized signal-to-noise ratio (db)	Noise factor (db)	Sensitivity for 1 failure in 1000 characters (db. rel. to 1 $\mu$ V)	Remarks
				Pre-detection	Post-detection					
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)
F1 (Fixed services)	1.6-30	400	50	( <sup>2</sup> )	45		17	7	-18.2	Two receivers tested
		400	50	( <sup>2</sup> )	90		19	7	-16.2	
		400	50	( <sup>2</sup> )	180		23	7	-12.2	
		200	50	( <sup>2</sup> )	100		19.2	7	-16	

Source impedance = 75  $\Omega$

(<sup>1</sup>) Doc. 2 of Warsaw, 1956, and Docs. II/3, II/11 and II/23 of Geneva, 1958.

(<sup>2</sup>) Pre-detector bandwidth unknown.

ANNEX VI

REPRESENTATIVE VALUES FOR THE MAXIMUM SENSITIVITY OF SOUND BROADCASTING RECEIVERS

(See § 10.1 of the Recommendation for the definition of maximum sensitivity)

TABLE X  
Maximum sensitivity for sound broadcasting receivers<sup>(1)</sup>

Class of emission	Service	Frequency range (Mc/s)		Maximum sensitivity (db rel. to 1 $\mu$ V)	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	

<sup>(1)</sup> See Doc. II/21 of Geneva, 1958.

Source impedance = 75  $\Omega$   
 Deviation =  $\pm 22.5$  kc/s  
 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\*.
- 1.2 The Tables on page 135 contain representative values for the sensitivity of the vision and sound channels of typical television receivers, as required by Question 228 (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) The significance of these columns is the same as for the columns with corresponding (5) and (6) 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).

\* See Recommendation 238.

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  $\Omega$

Width of overall effective noise band = 3 Mc/s.

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) The significance of these columns is the same as for the columns with corresponding (5) and (6) 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" \*.

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  $\Omega$

Width of the effective noise band = 4.6 Mc/s 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) The significance of these columns is the same as for the columns with corresponding (5) and (6) 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 c/s.

\* See Doc. 398 of Warsaw, 1956 and Doc. II/3 of Geneva, 1958.

TABLES XI TO XIV

Sensitivity and noise factor for television receivers

Frequency range (Mc/s)	Class of emission	(3)	Maximum usable sensitivity noise-limited	Maximum usable sensitivity gain-limited	Maximum sensitivity	Noise factor (db)	Remarks	
			(db relative to 1 $\mu$ V)					
(1)	(2)	(3)	(4)			(5)	(6)	
TABLE XI <sup>(1)</sup> (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 <sup>(2)</sup> (625-line system, video band 5 Mc/s and 525-line system, video band 4.2 Mc/s)								
41-68	A5 Picture	Max. Mean Min.	43		36	11.8 7.5 4	Mass-production receivers Noise factor for 20 receivers tested	
	F3 Sound	Max. Mean Min.	34.5					
174-216	A5 Picture	Max. Mean Min.	49		44	11.8 7.5 5		
	F3 Sound	Max. Mean Min.	40.5					
470-890	A5 Picture	Max. Mean Min.				18 12 9	Ten receivers of different types tested	
TABLE XIII <sup>(3)</sup> (625-line system, 6 Mc/s 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 of Geneva, 1962.

(2) See Docs. 398 of Warsaw, 1956, II/3 of Geneva, 1958 and II/31 of Geneva, 1962.

(3) See Doc. 215 of Warsaw, 1956.

## RECOMMENDATION 332 \*

## SELECTIVITY OF RECEIVERS

The C.C.I.R., (London, 1953 – Warsaw, 1956 – Los Angeles, 1959 – Geneva, 1963)

## 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, § 1.2), together with an allowance for the unavoidable instabilities of the frequencies of the transmitter and of the receiver;
2. 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, § 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;
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 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;

---

\* This Recommendation replaces Recommendation 235.

4.3 *image-response ratio* : the image-response ratio is the ratio:

- of the input signal level at the image frequency required to produce a specified output from the receiver,
- to the level of the wanted signal required to produce the same output.

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 there will be a corresponding image-response ratio;

4.4 *intermediate-frequency response ratio* : the intermediate-frequency response 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 from the receiver,
- to the level of the wanted signal required to produce the same output;

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 ratio* : the spurious-response ratio is the ratio:

- of the input level at the interfering frequency required to produce a specified output from the receiver,
- to the level of the wanted signal to produce the same output;

5. that single-signal measurements be made of the pass-band, the attenuation slope, the image-response, the intermediate-frequency response and other spurious-response 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, cross-modulation and inter-modulation 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 due to a modulated \* wanted signal of specified level applied to the receiver input:

\* Except for A1 signals when an unmodulated carrier is used.

- 6.3 *cross-modulation* : cross-modulation is measured by the level of a modulated unwanted signal on a frequency near to an unmodulated wanted signal (e. g. in an adjacent channel), which results in an output from the receiver of a specified amount (e. g. 20 db \*), below that which would be obtained if the wanted signal were modulated;
- 6.4 *inter-modulation* : inter-modulation is measured as the levels of two unwanted signals which, when applied together, produce at the receiver output 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 ( $E_{if} = F_n' + F_n''$ ), 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 products may occur; those selected are generally sufficient to describe the performance in respect of 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 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  $\mu$ V. (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 inter-modulation product and the carrier of the wanted signal, is more severe than that due to any modulation; in receivers for A3b they should also be unmodulated and the frequency of one unwanted signal should be adjusted to make the output of the receiver have a frequency equal 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, cross-modulation and inter-modulation 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 229 (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 of the unwanted signals should be modulated. A correction should be made for the depth of modulation.

\* Other values may be desirable for certain classes of receivers.

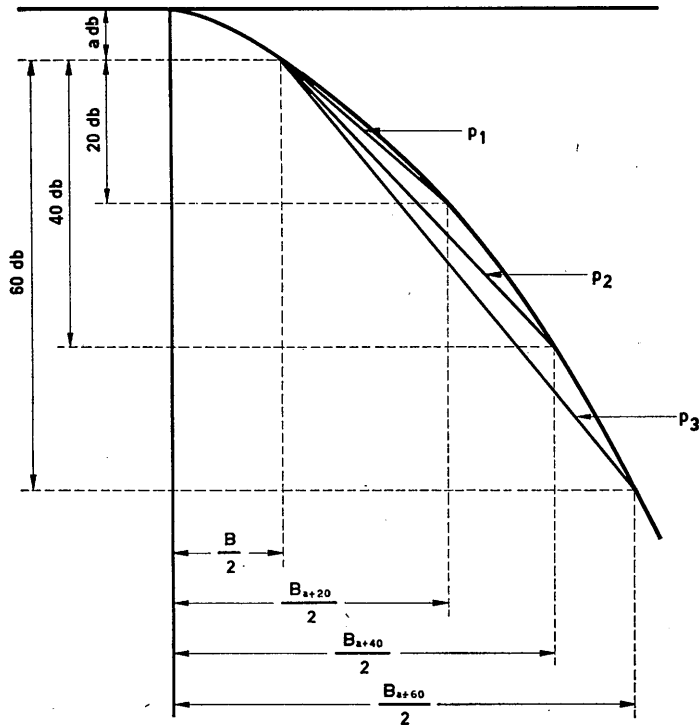


FIGURE 1

*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 kc/s
- $B$  = the bandwidth of the passband in kc/s as given in column (5) of Tables I, II and III
- $P_n$  = slope of the attenuation in db/kc/s as given in column (6) for:
- $n$  = an integer (1, 2, 3 or 4).

*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 of Warsaw, 1956, II/4, II/12, II/16, II/17 and II/25 of Geneva, 1958, 89 of Los Angeles, 1959, and II/2, II/10, II/23 and II/30 of 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 of Warsaw, 1956, II/25 and II/29 of Geneva, 1958 and II/31 of Geneva, 1962. Some of the data given in Annexes I and II were collected as part of studies required by Question 229(II).

Annex III gives representative values for the two-signal selectivity of FM broadcast receivers and is based on Doc. II/25 of Geneva, 1958.

Annex IV gives representative values for time-delay/frequency characteristics of high frequency radiotelegraphy receivers and is based on data and information given in Docs. II/14 and II/15 of 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 values 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.
- (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 be 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 inter-modulation)* (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,  $F_d$ , 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 Table 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 of 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) 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.
- (9) (10) (11)
- (12) Remarks on the design of receivers.

ANNEX I

TABLE I

Single-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range (Mc/s)		RF and IF passband (kc/s)	Attenuation slope from edge of passband (db/kc/s)				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)	
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 <sub>o</sub> +f <sub>if</sub> : 137 db 2f <sub>o</sub> +f <sub>if</sub> : 123 db f <sub>o</sub> +1/2f <sub>if</sub> : 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 (Mc/s)		RF and IF passband (kc/s)	Attenuation slope from edge of passband (db/kc/s)				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	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		
	General purpose	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			30	81		
General purpose	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			
General purpose	30-300	Min.	16.5	0.84	0.9	0.9	0.9		22	82		
		Max.	65	5	4.4	3.6	3		100	109	3 groups of 4 receivers (of different types) tested	
Mobile	30-300	Mean	37	3.2	2.7	2.3	1.4		60	90		
		Min.	22	1.5	1.1	1.5	1.1					
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	
Fixed	1.6-30	Max.	7.3	45					115	126	23 receivers tested of 4 different types	
		Mean	6.9	13.3				61	60			
		Min.	6.1									
Fixed	2.5-21			6	50	55	70	37		> 90	> 75	$f_o - f_{if_2} > 78$ db

TABLE II-B

(1)	(2)	(3)	(4)	(5)	(6)				(7)	(8)	(9)	(10)	
F3	Fixed	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	
		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 <sup>(2)</sup>		1500	0.03	0.03				70	140	2f <sub>o</sub> +f <sub>if</sub> : > 130 db		
	30-300		40	0.8	0.8				90/44	>100			
	General purpose	65-175		28 <sup>(1)</sup>	1.5 <sup>(1)</sup>	1.5 <sup>(1)</sup>	1.5 <sup>(1)</sup>	1.5 <sup>(1)</sup>		> 70	>100	Receiver with continuous tuning. Single frequency change	
	Mobile	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 <sup>(3)</sup> 92 118 <sup>(3)</sup>	96 92 76	100 <sup>(3)</sup>	13 receiver tested (of different types) <sup>(3)</sup>	
		30-300		55	1.2	1.2	1.2	1.1	47	70	80	Portable rec. 25 recs. tested (of 2 types)	
		68-87.5		30 <sup>(1)</sup>	3 <sup>(1)</sup>	3 <sup>(1)</sup>	3 <sup>(1)</sup>	3 <sup>(1)</sup>			> 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 <sup>(1)</sup>	2.3 <sup>(1)</sup>	2.3 <sup>(1)</sup>	2.3 <sup>(1)</sup>	2.3 <sup>(1)</sup>			> 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)	

<sup>(1)</sup> At 3 db down and, therefore, at 23, 43, 63 and 83 db. <sup>(2)</sup> Measurements made at the single frequency shown. <sup>(3)</sup> See also Doc. 446 of Warsaw, 1956.

TABLE III  
Single-signal selectivity of sound broadcast receiver

Class of emission	Service	Frequency range (Mc/s)		RF and IF passband (kc/s)	Attenuation slope from edge of passband (db/kc/s)				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	Sound broadcasting	1.6-30	Max.	13.3	4.5	3.75				44	120	10 receivers tested	
			Mean	8.05	3.6	3.1				25	90		
			Min.	4.0	2.5	2.1				9	57		
		0.5-30	Max.	15.0	8.9	6.7	6.3				78 <sup>(1)</sup>	100 <sup>(1)</sup>	169 receivers of about 20 types tested
			Mean Min.	7.3 4.0	3.3 1.2	3.4 1.8	3.1 2.0				28 <sup>(1)</sup> 22 <sup>(1)</sup>	96 <sup>(1)</sup> 68 <sup>(1)</sup>	
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 <sup>(2)</sup>		6	3.3	1.3					38	36	$2f_o + f_{if}$ : 63 db $f_o + 1/2 f_{if}$ : 96 db		
0.5-10	Mean	10.0	4.3	6.1							Low price receiver of 1 type (24 000 tested)		
F3	Sound broadcasting	86-100								20	32	FM/AM battery receiver	
										37 21 13	42 51 28	FM/AM receiver FM/AM receiver FM/AM battery receiver	
			90 <sup>(2)</sup>		125 <sup>(3)</sup>	0.19 <sup>(3)</sup>	0.17 <sup>(3)</sup>				23	68	FM tuner. Switched with a.f.c. Cheap broadcast receivers
88-100		165 <sup>(3)</sup>	0.28 <sup>(3)</sup>	0.27 <sup>(3)</sup>							High-quality broadcast receivers		

(<sup>1</sup>) 3 receivers of different types tested.

(<sup>2</sup>) Measurements made at the single frequency shown.

(<sup>3</sup>) At 3 db down and, therefore, at 23 and 43 db (in column 6).

TABLE IV/1-A

Two-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency range (Mc/s)	Signal separation $F_d - F_n$ (kc/s)		Blocking Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) of:				Cross-modulation Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) 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
	Fixed	1-6-30	20	Max. Mean Min.	72 69 66	80 77 73	88 85 80	93 91 87	69 64 63	77 73 71	84 81 79	89 87 85	3 receivers tested
A1	General purpose	0-03-30	10	Max. Mean Min.		106 81 70	115 101 86	123 115 104		90 77 59	101 91 83	113 104 100	3 receivers of different types tested at 2 frequencies
F1	Fixed	1-6-30	20	Max. Mean Min.	102 94 85	113 102 88	>120 >111 94	>120 >115 102	96 89 87	>120 >120 >120	>120 >120 >120	>120 >120 >120	9 receivers tested
A1 A2	Fixed	3-24	5	Max. Min.	83 80	104 102	111 108						
			2	Max Min.	72 72	93 92	113 111						

TABLE IV/1-B

Two-signal selectivity of radiotelegraphy receivers

Class of emission	Service	Frequency of wanted signal (Mc/s)	$F_a - F_n$ (kc/s)	Blocking				Cross-talk				Inter-modulation			Remarks		
				Level of unwanted signal (db rel. 1 $\mu$ V) 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 $\mu$ V)				Level of unwanted signal (db rel. 1 $\mu$ V) for an output 20 db below the value; the levels of the wanted signal being: (db rel. 1 $\mu$ V)				Frequency of wanted signal (Mc/s)	Levels of two unwanted signals (db rel. 1 $\mu$ V) which produce standard output and a signal-to-noise ratio of 20 db				
				+20	+40	+60	+80	+20	+40	+60	+80		$F_n' - F_n'' = F_{if}$	$F_n' + F_n'' = F_a$		$F_n' - F_n'' = F_a$	
(1)	(2)	(3)	(4)	(5)				(6)				(7)	(8)			(9)	
F1	Fixed	3.1	5 10 15	77 94 100	92 100	102 >120	>120 >120										50 bauds. Shift 800 c/s. IF bandwidth 2 kc/s
A1	Fixed	3.1	5	104													100 bauds. Shift 400 c/s. IF bandwidth 1 kc/s
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 c/s. IF bandwidth 1 kc/s
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 V/1-A

Two-signal selectivity of radiotelephony receivers

Class of emission	Service	Frequency range (Mc/s)	Signal separation $F_a - F_n$ (kc/s)		Blocking Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) of:				Cross-modulation Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) 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	
									77	89		2 receivers tested	
	0-03-30	50										2 receivers tested	
30-300	1000								100 <sup>(1)</sup>				

(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 (Mc/s)	Signal separation $F_d - F_n$ (kc/s)		Blocking Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) of:				Cross-modulation Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) 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 <sup>(1)</sup>	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 (Mc/s)	Input level of wanted signal (db mW)	Unwanted-to-wanted signal ratio (db) for a wanted-to-unwanted output ratio of 30 db, with frequency separations, of (kc/s)								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 kc/s 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 (Mc/s)	$F_d$ (Mc/s)	Intermodulation																				Remarks				
				Level of unwanted signals (db rel. 1 $\mu$ V) 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)			
A3	Fixed	1-6-30	10	Max.	(-)		91	>104	>104	>104	(-)		84	93	99	103											4 receivers tested	
				Mean	0.5		84	> 94	>101	>101	15.1		80	86	95	101												
		Min.			79	81	90	87			79	81	93	97														
		Max.								(+)		86	86	>104	>104													
	5-22	10	Max.			>104	22.1	>104																				
			Mean			>104	10.1	>104																				
	0.03-30	10	Max.	(-)		100				(-)		90																Receivers of different types
			Mean			85						77																
30-300	50	Max.							(+)		100															1 receiver tested		
		Mean									93																	
General purpose	30-300	30		Max.	(-)		82			(-)	84																	
				Mean									90															
General purpose	30-300	50		Max.	(-)		90			(-)	81																	
				Mean									96															

(<sup>1</sup>) In these columns the values inserted are those for the frequencies given by the following: (a) for (+):  $(F_{n'} - 1/2 F_{IF})$ ; for (-):  $(F_{n'} - F_d)$ ; (b) for (+):  $(F_{n'} - 1/2 F_d)$ ; for (-):  $(F_{n'} - F_d)$ ; (c)  $(F_{n'} - 1/2 F_{im})$ ; (d)  $(F_{n'} - F_d)$ .



TABLE VI/1

Two-signal selectivity of sound-broadcast receivers

Class of emission	Service	Frequency range (Mc/s)	Signal separation $F_a - F_n$ (kc/s)		Blocking Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) of:				Cross-modulation Level of unwanted signal (db rel. 1 $\mu$ V) for level of wanted signal (db rel. 1 $\mu$ V) 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 <sup>(1)</sup>		
								109		124	"Narrow" bandwidth } High-quality broadcast receiver		
								102		124			
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 <sup>(1)</sup>
		88-100	300					43					High quality broadcast receiver <sup>(1)</sup>

<sup>(1)</sup> 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 (Mc/s)	$F_d$ (Mc/s)	Intermodulation																Remarks				
				Level of unwanted signals (db rel. 1 $\mu$ V) 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.								
				$a^{(1)}$	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 broadcast-ing	0.5-1.6	1	Max.	(-)	>90				(-)	>90												7 receivers tested	
				Mean		78				(-)	72													
		Min.		58																				
		Max.	(+)	>90				(+)	>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													

(<sup>1</sup>) In these columns the values inserted are those for the frequencies given by the following: (a) for (+):  $(F_{n'} - 1/2 F_{IF})$ ; for (-):  $(F_{n'} - F_d)$ ; (b) for (+):  $(F_{n'} - 1/2 F_d)$ ; for (-):  $(F_{n'} - F_d)$ ; (c)  $(F_{n'} - 1/2 F_{IM})$ ; (d)  $(F_{n'} - F_d)$ .

ANNEX II

TABLE VII

Single-signal selectivity of television receivers

Class of emission	Frequency range (Mc/s)		Attenuation (db), relative to maximum response, at the frequency shown below in (Mc/s) relative to vision carrier frequency <sup>(1)</sup>														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)			
<i>(a) 405-line system</i>																					
Sound carrier									Vision carrier												
A5 (vision)	30-100	Max. Mean Min.							>60 >60 40	>60 >60 18	>60 >60 32	>54 >40 36	20 15 10	5 3 1	1 0 0	0 0 0	9 6 4	27 23 20	46 41 37	4 receivers tested	
	30-300	Max. Mean Min.							>50 >40 26	>50 >40 26	>50 >37 25	>60 >50 45	46 24 6	24 9 1	6 2 0	2 1 0	6 4 0	18 13 6	40 30 17	5 receivers tested	
		Max. Mean Min.							42 37 35	36 29 25	35 28 25	>50 >50 >50	29 20 8	13 8 1	4 1 0	4 2 0	2 2 0	15 10 6	23 21 17	3 receivers tested	
	56-75								41	29	26	58		2	0	0	3	14	20	48	
	41-68	Max. Mean Min.							73 56 46	56 43 35	52 41 25	72 54 40	36 24 13	16.5 7 1	3 2 0	1 0.5 0	7 2.2 0	16 8.5 3.5	29 20 12	56 42 23	7 receivers tested
		Max. Mean Min.							43 40 37	40 37 33	42 37 30	65 54 48	38 21 12	18 7 1	3 1.5 0	1 0.5 0	5 3 1	14 9 2	24 17 6	46 43 40	3 receivers tested
174-216	Max. Mean Min.							43 40 37	40 37 33	42 37 30	65 54 48	38 21 12	18 7 1	3 1.5 0	1 0.5 0	5 3 1	14 9 2	24 17 6	46 43 40	3 receivers tested	
A3 (sound)	41-68	Max. Mean Min.						70 48 27	50 32 17	20 11 3	0	12 10 5	36 25 12	56 37 18	37	42	49	60	>80	4 receivers tested	
	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. Mean Min.																		87 59 42		
	195	Max. Mean Min.																			74 59 47	10 receivers of different types tested
	470 890	Max. Mean Min.																			57 40 28	

*(c) 625-line system*

			Adjacent vision carrier				Sound carrier				Vision carrier				Adjacent sound carrier					
A5 (vision)	100-300	Max. Mean Min.	58 43 33	38 31 27	36 25 12	40 23 15	12 7.7 5		5 1.2 0		3 0.7 0		1.4 0.7 0	2.5 0.9 0	6	21 14 10		45 40 32		4 receivers of different types tested
	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.

ANNEX III

TABLE VIII-A

Two-signal FM (F3) broadcast receiver selectivity

Service	Frequency of wanted signal (Mc/s)	Input 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 (kc/s) of								Remarks All new receivers and not realigned before test	
			0	±100		±200		±300		±400		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				-100	+100	-200	+200	-300	+300	-400	+400	
	94	-80 -60 -40		-10 -11.5 -10	-9.5 -5.5 -11	+1 -9.5 -9.5	-9.5 +4 -8.5	+15.5 -4.5 -6	-5.5 +16.5 +2.5	+26 +4.5 -1	+5 +27 +20	1 RF 2 IF ratio detector
	94	-80 -60 -40		-5 -6 +0.5	-10 -13 -1	-1.5 -0.5 +4	-9.5 -13 -0.5	+4.5 +6 +8	-7.5 -14 +2	+12 +13 +15	-4 -10 +6	1 RF 2 IF ratio detector
	92	-80 -60 -40		+2.5 -10.5 -12	+1 -8 -10	+3.5 -7 -7.5	+12 +0.5 -4	+14 +2.5 -0.5	+24 +13 +4.5	+32.5 +14 +8	+36 +27.5 +7.5	1 RF 2 IF ratio detector
	94	-80 -60 -40		-10.5 -10.5 -11.5	-6.5 -6.5 -11	+1 0 +4.5	+4 +3 -6	+35 +25	+36 +21.5 +11	+44 +33	+48 +33	3 IF ratio detector. Battery operated
F3	94	-80 -60 -40		0 -13.5 -13.5	-8 -1.5 -11	-3 -14.5 -13	+6 +6 +0.5	-3.5 -10.5 -12.5	+20 +16 +14	+11 +5.5 +2.5	+32 +24.5	1 RF 1 IF 1 limiter Foster Seeley Discriminator
	92	-80 -60 -40		-3 -3 -10	-4 -3.5 -10	-2.5 -1.5 +0.5	+3 +4 -8	+5.5 +3.5 -17.5	+13 +15 -5.5	+13 +13 -15	+24 +22.5 +1	1 RF 2 IF ratio detector
	94	-80 -60 -40		-7 -6.5 -17.5	-6.5 -5.5 -20.5	+7.5 +10 -4	-5 -10 -21.5	+25 +27.5 +12.5	+9 -2 -15	+40	+23 +15.5 +2.5	1 RF 3 IF ratio detector
	92	-80 -60 -40		-7.5 +1.5 -7.5	-5.5 -7.5 -11	-7 -3.5 +2	+0.5 -2 -6.5	+1 +5	+8.5 +5.5 -11	+16 +19.5	+18 +15 -3.5	1 RF 2 IF ratio detector
	94	-80 -60 -40	-13 -12 -16	-9.5 -3.5 -8	-6 -9.5 -13.5	0 +20 +15	+10.5 +1.5 -10	+24.5 +33	+32 +18 +9	+45.5	+48	3 IF ratio detector. Battery operated

TABLE VIII-B

## Two-signal FM (F3) broadcast receiver selectivity

Service	Frequency of wanted signal (Mc/s)	Input 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 (kc/s) 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 -60 -40	-15 -16 -14	-15 -5 -1.5	-17 0 -1.5	+2.5 +1 +2.5	+4 +9 +6.5	+10.5 +5 +4.5	+5 +16 +11	+17.5 +8 +8	+14 +22 +15	1 RF 2 IF ratio detector
	94	-80 -60 -40	-8 -14 -10.5	+1 -11.5 -6.5	-4 -7 +0.5	+22.5 +1 +6.5	+2 +17.5	+37.5 +16	+12 +28.5	+47.5 +26	+37 +34	No RF 2 IF ratio detector Battery operated
	94.5	-80 -60 -40	-13 -11 -8	-6 -8 -6	-6.5 +0.5 +2.5	-1.5 -8 -4	-4 +4.5 +6.5	+3.5 -1.5 -3.5	+3.5 +9 +10	+13 +7 -0.5	+11 +18 +17	1 RF 2 IF ratio detector
	91.3	-80 -60 -40	-11 -11 -10	-8 -3.5 -6	0 +2 +2.5	-3 -8 -6.5	+12 +16 +12	+7.5 +0.5 +4.5	+22 +25	+20.5 +11	+30 +33.5	1 RF 1 IF Foster Seeley Discriminator
	95	-80 -60 -40	-9 -11 -9	-5 -12 -8.5	-1 -25 -8	-1.5 -10.5 -10.5	+8 +11.5 -2	+11.5 +3 -4	+18 +25 +6.5	+25 +22 +13	+32.5 +37	1 RF 2 IF ratio detector
F3	95	-80 -60 -40	-13 -11 -12	-11.5 -6 -5	-10 5 -2	-3.5 +1.5 +3.5	-2 +2.5 +8	+11 +13 +6	+9.5 +11 +11.5	+24 +16.5 +6	+22 +17.5	1 RF 2 IF ratio detector
	94	-80 -60 -40	-7 -11 -11	-5 -6 -5		0 +2 +3		+12 +13 +15		-21 +24 > +20		1 RF 2 IF ratio detector
Frequency separation (kc/s)			0	-25	+25	-50	+50	-75	+75	-100	+100	
F3 fixed	165.7	-80 -60 -40	-6 -6 -6	-9 -6 +1	-7 -5 -6	+55	+53 +36					2 receivers of same type designed for 50 kc/s channel spacing
F3	166.75	-80 -60 -40	-8 -8 -7	+26 +29	+22 +23		+57					

## ANNEX IV

TABLE IX

*Group-delay characteristics of radiotelegraphy receivers*

Classification (*)	Passband (c/s)	Attenuation slope (db/100 c/s)		Group-delay time at centre frequency $f_0$ (20 kc/s) (ms)	Maximum deviation of group-delay time within the specified bandwidths by attenuations of 3,6 and 12 db. The value of $f_0$ is taken as a reference (ms)						Remarks
		26 db	46 db		3 db		6 db		12 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 c/s
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 c/s
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			

(\*) In the receivers classified A, the filters used were designed to have flat group-delay/frequency characteristics, whereas for B, they were designed by conventional methods.

RECOMMENDATION 333 \*

TUNING STABILITY OF RECEIVERS

The C.C.I.R.,

(London, 1953 – Warsaw, 1956 –  
Los Angeles, 1959 – Geneva, 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 cycles, 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) of 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.) of Geneva, 1958; in Doc. 122 (U.S.S.R.) of Los Angeles, 1959 and in Doc. II/9 (United Kingdom) of Geneva, 1962. These assembled data constitute a partial reply to Question 230 (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 Mc/s 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.
- (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.
- (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:  
± 10% for AC mains supply  
± 20% for battery supply
- (9) The relative frequency variation is:
  - either that due to 1° C variation 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.

TABLE I

Radiotelegraphy receivers

Reference	Class of emission	Service	Frequency range (Mc/s)	Crystal-controlled frequency changer used		Relative frequency drift ( $\times 10^{-9}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-6}$ ) due to supply voltage variation of:		Relative frequency variation ( $\times 10^{-6}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-6}$ ) 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		$f_{osc} = 2$ Mc/s $f_{osc} = 16$ Mc/s $f_{osc} = 27$ Mc/s	} Variation over whole range. Only a few receivers tested
3(W)	A1 A2 F1	Fixed	3-30	Yes <sup>(1)</sup>	Mean	{	323 122 17	237 66 6	186 19 2	0 0 0	42 13 1	2.9 1.3 3.2				$f_{osc} = 7$ Mc/s $f_{osc} = 16$ Mc/s $f_{osc} = 24$ Mc/s	
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		

<sup>(1)</sup> Frequency synthesis employed

TABLE II  
Radiotelephony receivers

Reference	Class of emission	Service	Frequency range (Mc/s)	Crystal-controlled frequency changer used		Relative frequency drift ( $\times 10^{-9}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-9}$ ) due to supply voltage variation of:		Relative frequency variation ( $\times 10^{-9}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-9}$ ) 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)	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 <sup>(1)</sup>		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 kc/s
7(W)	F3	Fixed	163.5	Yes	Mean		19	11	0		3.6				3.5	IF bandwidth 35 kc/s
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° to 10° 0°C to 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 (Mc/s)	Crystal-controlled frequency-changer used		Relative frequency drift ( $\times 10^{-9}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-9}$ ) due to supply voltage variation of:		Relative frequency variation ( $\times 10^{-9}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-9}$ ) 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)	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 (Mc/s)	Crystal-controlled frequency-changer used		Relative frequency drift ( $\times 10^{-6}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-6}$ ) due to supply voltage variation of:		Relative frequency variation ( $\times 10^{-6}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-6}$ ) 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 (Mc/s)	Crystal-controlled frequency changer used		Relative frequency drift ( $\times 10^{-6}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-6}$ ) due to supply voltage variation of:		Relative frequency variation ( $\times 10^{-6}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-6}$ ) 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 <sup>(1)</sup>		350 <sup>(1)</sup>	Only a few receivers tested

<sup>(1)</sup> Approximate values.

TABLE VI  
*General purpose high stability receiver with compensating capacitor*

Reference	Class of emission	Service	Frequency range (Mc/s)	Crystal-controlled frequency changer used		Relative frequency drift ( $\times 10^{-6}$ ) at the following times (in minutes) after switching on					Relative frequency variation ( $\times 10^{-6}$ ) due to supply voltage variation of 10%	Relative frequency variation ( $\times 10^{-6}$ ) due to temperature variation of:		Relative frequency variation ( $\times 10^{-6}$ ) 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 ( $\times 10^{-6}$ ) at the end of the following times in hours			Relative frequency variation ( $\times 10^{-6}$ ) due to supply voltage variation of 10%		Relative frequency variation ( $\times 10^{-6}$ ) due to mechanical shock
						1	6	12			
(1)	(2)	(3)	(4)	(5)	(6)	(7)			(8)	(9)	(10)
1		General purpose	Tested at 20 Mc/s	Automatic correction		25.3 <sup>(1)</sup>			1.8		3.5
2		General purpose	Tested at 20 Mc/s	Automatic correction					1.8		3
3		General purpose	Tested at 20 Mc/s	1st crystal oscillator <sup>(2)</sup>		11 <sup>(3)</sup>			<0.3		
4		General purpose	Tested at 20 Mc/s	1st crystal oscillator <sup>(2)</sup>		24 <sup>(1)</sup>			0.3		0.9

<sup>(1)</sup> Measurement started 5 minutes after switching on.

<sup>(2)</sup> 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).

<sup>(3)</sup> Measurement started 60 minutes after switching on (including thermostat).

## RECOMMENDATION 334 \*

RESPONSE OF BROADCAST AND TELEVISION RECEIVERS  
TO IMPULSIVE AND QUASI-IMPULSIVE INTERFERENCE \*\*

(Question 175(II))

The C.C.I.R.,

(Warsaw, 1956 – Geneva, 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 Mc/s to 30 Mc/s \*\*\*;
  - Publication 2: specification for C.I.S.P.R. radio-interference measuring apparatus for the frequency range 25 Mc/s to 300 Mc/s \*\*\*;

## 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 175 (II) and Report 183.

\*\*\* Available from the I.E.C. Central Office, Geneva.

## REPORTS OF SECTION B: RECEPTION

## REPORT 183 \*

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

(Question 175(II))

(Los Angeles, 1959 – Geneva, 1963)

1. As mentioned in Recommendation 334, the expression *quasi-impulsive interference* can be interpreted in different ways. Here is meant 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, high-frequency plastic-welding machines, etc. The man-made noise may for certain periods of time, occur quasi-periodically, with fairly constant shape and amplitude. Such interference requires special methods of measurement, and the calculation of its effects on the receivers is difficult.

2. *Atmospheric noise* has been studied for many years. A few recent papers are listed in the Bibliography below (see also Recommendation 372, Resolution 8, Report 322, Study Programmes 3A(III) and 199(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 analyzed in terms of r.m.s., average, median, peak, quasi-peak, or mean logarithmic values. Calibration may be referred either to absolute field strength of intensity, or by ratio to the thermal noise level.

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

\* This Report, which replaces Report 99, was adopted unanimously.

\*\* 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.

4. Studies have also been made of the variation of noise power over the frequency spectrum. In general, this variation is slow, so that the portion of the spectrum within the passband of a narrow band receiver may be considered uniform (white noise). For wider passbands this would not hold, especially as the frequency limits for ionospheric propagation are approached.
5. It can be concluded that the mean energy produced in a receiver by natural noise must be proportional to the bandwidth  $B$ ; the r.m.s. voltage is therefore proportional to  $\sqrt{B}$ .

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  $\sqrt{B}$ .

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

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

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

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

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

This can be done in two stages.

- 6.1 Probability of error on an isolated element of a binary code. It has been shown and verified that, for frequency shift reception, this probability is equal to *one-half* the probability of the corresponding level on the noise envelope ([2], pp. 21, 24, 25 and [4]).
- 6.2 Probability of error on a character containing a given number of binary elements. For example, with the 5-unit code, if each "unit" is affected by the probability of error,  $p$ , and if these probabilities are independent, the probability of error on a character is ([2], p. 23):

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

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.

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

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

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

Let us consider, for instance, the case of 3 or 4 successive noise impulses, whose individual durations (including any lengthening by the 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:

$$P' \approx 1 - (1 - p)^7 \\ \approx 7p \text{ (if } p \text{ is small)}$$

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

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

Thus (see [2], Table I), a receiver system may be characterized 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 kc/s.

*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%.

9. Studies carried out over many years have made it possible to assess the atmospheric noise distribution at the surface of the earth, as well as its variations with the hour of the day, season, ionospheric disturbances, etc. However, until recently, only the variations in the absolute level have been considered. Changes in the distribution of amplitude, variation rate, etc., have recently been reported [5, 7], and further work is being continued.
10. In conclusion, although quasi-impulsive atmospheric noise may be studied statistically like thermal noise, there is a sufficient difference between the two to warrant widely different and often divergent methods for reducing the effects of the former:
  - its “dynamic range” is much larger; consequently, the reduction of errors by raising the signal level is much less effective in this case;
  - the number of errors depends not only on the statistical amplitude distribution but also on the variation rate, i. e. the individual duration and the spacing of the noise signals in relation to the duration of the signal element; the variation rate has a marked effect even independently of the bandwidth of the receiver; \*
  - the method of reducing the effect of quasi-impulsive interference by reducing the radio-frequency bandwidth is less effective; with a good limiter, it may even be advantageous to increase the bandwidth.

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

11. As regards *man-made noise*, 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.

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

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 175 (II). The comments may be summarized as follows:

12. 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 c/s; or of the order of industrial frequencies, e. g. 50 or 60 c/s; or, again, higher than that, although rarely exceeding a few kc/s, i. e. the 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,  $F_0$ , can be calculated with only two parameters, i. e.

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

It is found, for instance [9], that in a linear receiver with a gain,  $G$ , each separate pulse produces a damped oscillation with a peak amplitude,  $U_{max} = GPB$ , 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.

13. *Standard interference generators* can be designed—and, in fact, exist already—for providing pulses with levels and rates that are adjustable and known, or random. They have been used to simulate the effects of non man-made noise [10].
14. The experimental measurement conditions required for evaluating and comparing the interfering signals from various sources of disturbance can be defined, and the extent to which they can be reduced through *interference suppressors* can be measured [9, 10 and other C.I.S.P.R. documents].
15. It has been suggested [8], that the effect of a continuous wave with a rapidly varying frequency, sweeping quickly through the passband of the receiver, may be likened to a *shock* and regarded as a short interfering signal of the type dealt with in § 12. This phenomenon, which is liable to arise with certain machinery using high frequencies, is worthy of further study.
16. On the basis of the above considerations, the following partial reply may be given to Question 175 (II).
- 16.1 The usable sensitivity of receivers may be reduced by quasi-impulsive interference in any service, depending on local conditions and the frequency range used [12].
- 16.2 The response of telegraph receivers to such interference can be calculated by measuring certain characteristics, e. g.:

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

The calculation is much more difficult for voice receivers.

- 16.3 Pulse generators can be used for simulation of some types of man-made noise [10]; but, as regards atmospheric noise, the Poisson distribution provides a poor approximation, and it is

better to simulate the real characteristics mentioned in § 16.2, or to use magnetic tape recordings with special techniques.

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

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

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

- 16.5 The maximum admissible interference level can only properly be calculated after performing the analysis described under § 16.4.

- 16.6 The impulse-limited sensitivity will be a function of:

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

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

#### BIBLIOGRAPHY

1. U.R.S.I. C.R. XIIth Assembly, Boulder 1957, Vol. XI, fasc. 4, Comm. IV (Crichlow Report).
2. WATT, COON, MAXWELL and PLUSH. The performance of some radio systems in the presence of thermal and atmospheric noise. *Proc. IRE*, **46**, 1914–1923 (December 1958).
3. WATT, COON and ZURICH. National Bureau of Standards, Report 5543, 1957, refers to Study Programme 43, rather than to Question 125.
4. C.C.I.R. Doc. 30 (Japan), of Los Angeles, 1959.
5. WATT and MAXWELL. Measured statistical characteristics of VLF atmospheric radio noise. *Proc. IRE*, **45**, 55–62 (January 1957).
6. FULTON. The effect of receiver bandwidth on amplitude distribution of VLF atmospheric noise. *Symp. propagation of VLF radio waves*, Boulder, Colorado, **3**, 37–1, 37–19 (1957).
7. HARWOOD. Atmospheric noise at frequencies between 10 kc/s and 30 kc/s. *Proc. I.E.E.*, **105**, part B, 293–300 (May 1958).
8. C.C.I.R. Doc. 166 (France), of Los Angeles, 1959.
9. C.I.S.P.R. Doc. R.I. (France) 204 (FROMY, E. Mesure du pouvoir perturbateur d'un matériel électrique prototype) (August 1953).
10. C.I.S.P.R. Doc. R.I. (France) 206 (FROMY, E. Les perturbateurs étalons) (August 1953).
11. C.C.I.R. Docs. 101 and 147 (U.S.S.R.), of Los Angeles, 1959.
12. C.C.I.R. Doc. II/20 (P.R. of Poland), of Geneva, 1962.
13. C.I.S.P.R. Doc. 310 (Belgium) and Doc. 319 (U.S.A.), Introduction of correlation functions in radio interference measurements (L. MORREN, P. JESPERS and R. DE VRE).

#### 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:

$$Q(V) = 1 - \exp \left\{ -0.693 \frac{V^2}{V_m^2} \right\}$$

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

2. Log-normal distribution

Putting  $x = \log(V/\bar{V})$ , the probability of an amplitude comprised between  $V$  and  $(V + dV)$  is:

$$q(V) \cdot dV = \frac{1}{\sqrt{\pi}} \exp. \{-x^2\} dx$$

and the overall probability of an amplitude greater than  $V$  is

$$Q(V) = \int_V^\infty q(V) dV$$

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

3. Law

$$Q(V) = [1 + (V/V_m)^q]^{-1}$$

$q$  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

$$b = 0.6 [20 \log_{10} (V_{rms}/\bar{V})]$$

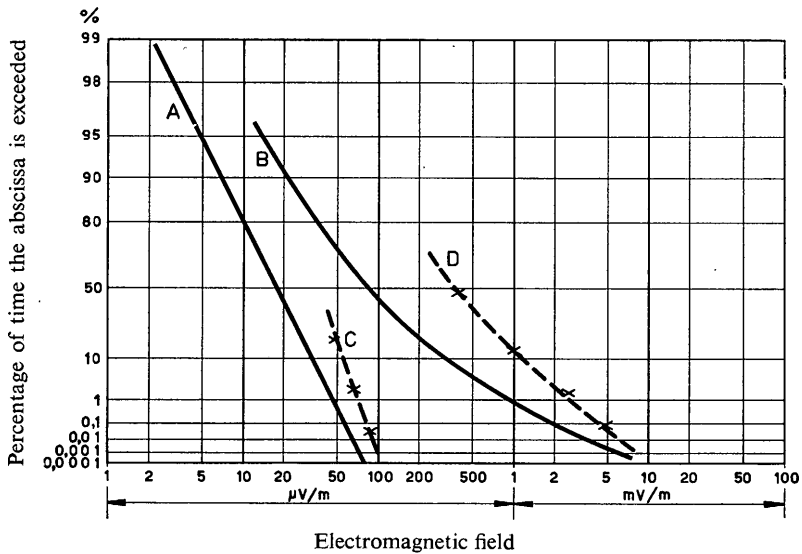


FIGURE 1

*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)

(Warsaw, 1956 – Los Angeles, 1959 – Geneva, 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 of Warsaw, 1956, Docs. II/1, II/4, II/13 and II/20 of Geneva, 1958 and Doc. 138 of 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 kc/s are commonly used. No specified value for the intermediate-frequency can be recommended, because it will be of advantage to be able to avoid interference by convenient choice of intermediate frequencies, according to the different situations with respect to powerful transmitters operating in these bands. Self-generated beats and whistles can be avoided by conventional technical means with any of the above-mentioned values. For receivers of high quality the problem need not be considered, as an adequate IF and image rejection is always assured.
  - 1.3 For domestic frequency-modulation receivers, the intermediate frequency of 10.7 Mc/s, normally used, is satisfactory provided that radiation by the receiver on the IF and its harmonics and at the frequency of the local oscillator and its harmonics, is sufficiently reduced.
  - 1.4 For monochrome television receivers, working in Bands I and III, there seems to be a general trend towards a national standardization of the IF channel. As several television systems are in use, and since, for any one system, there are different channel allocations in different countries, it seems impossible to propose only one preferred IF. Preferred values of intermediate frequencies in different countries for monochrome television receivers are shown in 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 IF. Anyhow, other technical means are already applied and used in the common techniques to avoid external

---

\* This Report, which replaces Report 98, was adopted unanimously.

TABLE I

Number of lines per picture frame	Country	Channel limits at intermediate frequency (Mc/s)	Intermediate frequency				
			Sound channel $f_s$ (Mc/s)	Video-channel $f_v$ (Mc/s)			
405	United Kingdom	33.4–38.4	38.15	34.65			
525	United States	41–47 <sup>(1)</sup>	41.25	45.75			
	Japan	22–28 <sup>(2)</sup>	22.25	26.75			
625	Spain Netherlands Federal Republic of Germany Switzerland	33.15–40.15	33.4	38.9			
	Italy				40–47 <sup>(2)</sup>	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		

<sup>(1)</sup> According to Electronic Industries Association Standard Rec. No. 109 C.

<sup>(2)</sup> Protected band.

and internal interference, so that practical results are quite 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 kc/s 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 Mc/s, the intermediate-frequencies used in receivers depend on the signal frequency and the desired image rejection. For receivers required to operate in the 500 kc/s maritime band, the commonly used intermediate-frequencies of 420 to 475 kc/s are clearly unsuitable. There, higher values, e. g. 530 to 700 kc/s, 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 kc/s, to provide the image rejection needed on the high frequency ranges, and the lower intermediate-frequency is usually about 100 kc/s.

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) of 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 Mc/s.

Maritime mobile receivers for the VHF band are usually of the double-superheterodyne type with a first IF of about 10 Mc/s; the second IF is often in the frequency range 400 to 500 kc/s. 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 IF is in the 2 Mc/s band, which is used by ships for radiotelephony. It is recommended that the bands 405 to 535 kc/s and 1605 to 2850 kc/s should be avoided when choosing the second IF for such receivers.

The values for minimum IF rejection ratio for receivers in the maritime mobile service are given in Table II:

Minimum IF rejection ratio (db)		
General purpose receivers 15 kc/s to 25 Mc/s	Radiotelephone equipment 1600-3700 kc/s	VHF receivers at about 160 Mc/s
60 <sup>(1)</sup>	60 <sup>(2)</sup>	90

<sup>(1)</sup> In the United Kingdom, an IF response ratio of 90 db is specified when the IF lies between 140 and 1600 kc/s.

<sup>(2)</sup> In the United Kingdom, an IF response ratio of 80 db is specified when the IF lies between 140 and 1600 kc/s.

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 IF band of a receiver used for another link, additional IF rejection may be necessary.

## REPORT 185 \*

### SELECTIVITY OF RECEIVERS

(Question 229 (II))

(Geneva, 1963)

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) of Geneva, 1962.

Table II gives the values of attenuation, for the frequency indicated, contained in Doc. II/30 (United Kingdom) of Geneva, 1962.

\* This Report was adopted unanimously.

TABLE I

(1)	(2)	(3)	$F_d$ (Mc/s)	(5)	Level of unwanted signals (db rel. 1 $\mu$ V)										Intermodulation										(7)
					for the level of the wanted signal given below										for the level of the wanted signal given below										
					$F_{n'} + F_{n''} = F_{im}$		$F_{n'} - F_{n''} = F_{im}$		$2F_{n'} - F_{n''} = F_d$				$3F_{n'} - F_{n''} = F_d$		$2(F_{n'} - F_{n''}) = F_{if}$		$3F_{n'} - 2F_{n''} = F_d$				$4F_{n'} - 3F_{n''} = F_d$				
					$a^{(1)}$	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	
(6)																									
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 Mc/s)
		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 Mc/s)
		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 Mc/s)
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 Mc/s)
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 455 kc/s)

(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 (Mc/s)	RF & IF passband (kc/s)	Attenuation slope for attenuation $A$ db rel. maximum response (db/kc/s)				Ultimate slope in db/octave	Spurious response ratio (db) when input frequency <sup>(1)</sup> (Mc/s) 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)	
F3	Fixed 30-300 Mc/s	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 superhetrodyne receivers of the same type 1st conversion local frequency $F_{o_1}$ 1st crystal oscillator operates at $\frac{1}{3} F_{o_1}$ 2nd intermediate frequency $F_{if_2}$
														94	
													106	$\frac{4}{3} F_{o_1} + F_{if_2}$	
													86	$\frac{4}{2} F_{o_1} + F_{if_2}$	
													86	$F_{o_1} + F_{o_2} + F_{if_2}$ ( <sup>2</sup> )	
													86	$F_{o_1} + F_{o_2} + F_{if_2}$	
		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	$\frac{4}{3} F_{o_1} + F_{if_2}$	
													76	$\frac{4}{2} F_{o_1} + F_{if_2}$	
													76	$F_{o_1} + F_{o_2} + F_{if_2}$	

(<sup>1</sup>)  $F_o$  : Frequency of first frequency-changing oscillator;  $F_{if}$  : First intermediate-frequency.

(<sup>2</sup>) Image frequency of second frequency-change.

## REPORT 186 \*

## MULTIPLE-SIGNAL METHODS OF MEASURING SELECTIVITY

(Question 229(II))

(Geneva, 1963)

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, § 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), of 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, of Geneva, 1962, first the voltage for 30% modulation of the wanted signal is measured at the output of the FM receiver without 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.) of Geneva, 1962, both wanted and unwanted signals are frequency-modulated by a frequency of 1 kc/s, 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) of Geneva, 1962, concerning receivers for A3B, A3 and A1 emissions. One of the unwanted signals was chosen close to the desired channel.
4. Intermodulation measurements with three signals have been reported in Doc. II/10 (Federal Republic of Germany) of Geneva, 1962. In this document, 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 F1, and A3B.

---

\* This Report was adopted unanimously.

## REPORT 187 \*

## PROTECTION AGAINST INTERFERENCE BETWEEN KEYED SIGNALS

(Study Programme 127(II))

(Geneva, 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 F1 emissions and a telegraph speed 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  $1 \times 10^{-4}$  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 telegraph speed 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), to vary the modulation of the RF 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  $\tau$  was determined from oscillograms:

Rectangular	$\tau \approx 0\%$	} relative to the total nominal duration of the element.
Rounded rectangular	$\tau = 4.9\%$	
Trapezoidal	$\tau = 14.2\%$	
Rounded trapezoidal	$\tau = 19.4\%$	
Approximately sinusoidal	$\tau = 51.3\%$	

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.

---

\* This Report was adopted unanimously.

- 2.3 *Keying speed* : Since the telegraph distortion indicator was only capable of operation at a keying speed of 50 bauds, this speed was chosen for the wanted signal. To avoid beats, the interfering signal generator was used, in general, at a keying speed 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), 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 kc/s for the receiver type A, and 80 db per 1 kc/s 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  $\mu$ V 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 Mc/s), 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/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  $\mu$ V was chosen for the tests, which gave a signal/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 were varied as in § 2.1. A series of curves resulted, of 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  $1 \times 10^{-4}$  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 kc/s. 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 kc/s. 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 3A(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

TABLE I \*

Receiver type A. Slope at the edges of the passband – 20 db per 1 kc/s

Signal shape		N'	D (c/s)	B <sub>n</sub> (c/s)	B <sub>r</sub> (c/s)	Δ <sub>f</sub> (c/s)	Remarks
Wanted	Interfering						
a	a b c d	1/1	210	545	1000	380 370 365 355	B <sub>n</sub> < B <sub>r</sub>
	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 <sub>n</sub> < B <sub>r</sub>
	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 <sub>n</sub> < B <sub>r</sub>
	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 <sub>n</sub> < B <sub>r</sub>
	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 <sub>n</sub> ≈ B <sub>r</sub>
a	a d	1/10	545	1215	1000	1775 1725	B <sub>n</sub> > B <sub>r</sub>

- \* D : Frequency shift (c/s)  
 B<sub>n</sub> : Necessary bandwidth in accordance with Recommendation 328 (c/s)  
 B<sub>r</sub> : Receiver bandwidth (c/s)  
 N' : (N<sub>d</sub>/N<sub>n</sub>) = 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 kc/s

Signal shape		N' (db)	D (c/s)	B <sub>n</sub> (c/s)	B <sub>r</sub> (c/s)	Δ <sub>f</sub> (c/s)	Remarks
Wanted	Interfering						
a	a	0	185	495	880	390 345	B <sub>n</sub> < B <sub>r</sub>
	d	– 6	185	495	880	625 580	
	d	–30	185	495	880	990 925	
a	a	0	170	465	450	370 320	B <sub>n</sub> ≈ B <sub>r</sub>
	d	– 6	170	465	450	615 565	
	d	–30	170	465	450	890 845	
c	a	0	170	465	450	365 305	B <sub>n</sub> ≈ B <sub>r</sub>
	d	– 6	170	465	450	605 555	
	d	–30	170	465	450	925 870	
d	a	0	170	465	450	420 370	B <sub>n</sub> ≈ B <sub>r</sub>
	d	– 6	170	465	450	660 630	
	d	–30	170	465	450	1040 975	
a	a	–30	115	355	450	880 830	B <sub>n</sub> < B <sub>r</sub>
d		–30	115	355	450	985 940	
a	a	–30	210	545	450	1045 1000	B <sub>n</sub> > B <sub>r</sub>

\* D : Frequency shift (c/s)  
 B<sub>n</sub> : Necessary bandwidth in accordance with Recommendation 328 (c/s)  
 B<sub>r</sub> : Receiver bandwidth (c/s)  
 N' : (N<sub>d</sub>/N<sub>n</sub>) = Power ratio between the wanted and interfering signals.  
 a : rectangular  
 b : trapezoidal  
 c : rounded trapezoidal  
 d : approximately sinusoidal.

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.

Since only two types of receiver were available, the results cannot be generalized.

## BIBLIOGRAPHY

1. SCHENK, E. Der Fernschreiberverzerrungsmelder, ein automatisches Prüfgerät (The teleprinter distortion indicator, an automatic test apparatus.) *NTZ*, **12**, 609-612 (1959).

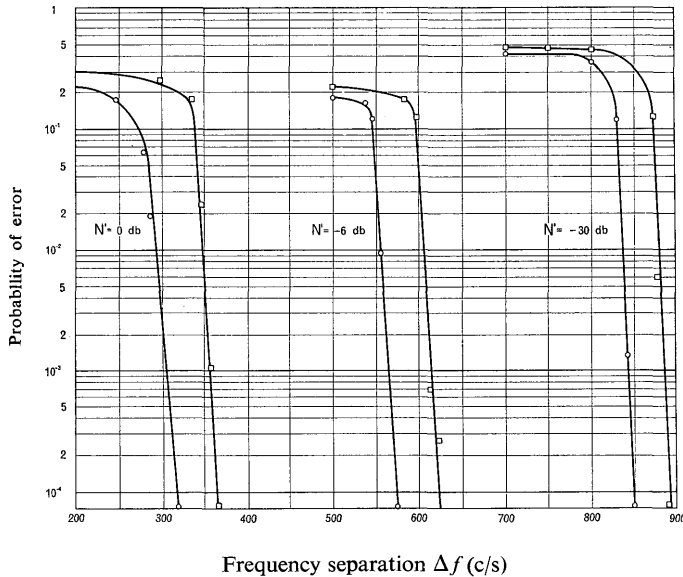


FIGURE 1

*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 \*

CRITERIA FOR RECEIVER TUNING

(Question 231(II))

(Geneva, 1963)

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.

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 12.1 of the I.E.C. Consequently, these criteria have been framed to line up broadly with I.E.C. documents for AM \*\*, FM and monochrome television receivers.

2.2 Receivers for AM 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 c/s (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 No. 69.

\* This Report was adopted unanimously.

\*\* This I.E.C. document is at present under revision; the draft proposals are available from the I.E.C. Central Office, Geneva.

### 2.3 *Receivers for FM sound broadcast (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 AM 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 of Geneva, 1962).

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 No. 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 IF and vision IF circuits. These differences can be functions of input signal level, as well as temperature.

### 2.5 *Receivers for monochrome television (525- and 625-line negative picture modulation) (A5C and F3)*

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 intercarrier 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 No. 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 pass-band 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 pass-band of this filter.

### 3.2 Radiotelegraph receivers for automatic reception (A1, F1 or F6)

The necessity of using the minimum pass-band to achieve the best performance in the presence of noise and other signals has led to the general provision of automatic frequency control. With 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 pass-band of the IF 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 pass-band.

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, of 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 criterion for tuning a double-sideband receiver is the same as that for an AM sound broadcast receiver.

## REPORT 189 \*

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

(Question 229(II))

(Los Angeles, 1959 – Geneva, 1963)

Question 229 (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.

\* This Report, which replaces Report 104, was adopted unanimously.

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) of Geneva, 1958: a method and a special apparatus for measuring the group-delay/frequency characteristics of intermediate frequency amplifiers in radio-telegraph receivers are introduced. It is well known that the intermediate-frequency stages have a predominating effect, especially in receivers used for high-speed 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 characteristic of receivers. Therefore, further contributions are invited from Administrations for studies to permit a decision on standard methods and apparatus.

#### 2. FM receivers

Doc. II/27 (France) of Geneva, 1962: this document describes a new method for measuring the distortions produced by crystal filters, used to obtain selection of the first intermediate-frequency in a superheterodyne receiver.

The method described consists in measuring the AF distortion produced by the crystal filtering equipment under consideration, coupled to a set comprising a wide-band amplifier, followed by a discriminator and an AF 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 used in FM radio-relay systems

Doc. II/33 (Italy) of Geneva, 1962: this document describes a highly accurate method for measuring group delay by determining the phase/frequency characteristics by a dynamic method.

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) of Warsaw 1956: a direct reading method of measuring group-delay/frequency characteristics is reported. In the apparatus described, by employing a special phase-detection valve as a phase meter, the characteristics can be observed on the screen of a cathode-ray oscilloscope. By using this apparatus in combination with a signal generator which has an automatic frequency sweeping device, the group-delay/frequency characteristics of intermediate-frequency amplifiers of television receivers can be measured with an accuracy of 1 manosecond.

4.2 Doc. 488 (Federal Republic of Germany) of 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.

#### BIBLIOGRAPHY

1. CATANIA, B. Misure di ritardo di gruppo in sistemi con modulazione di frequenza (Measurement of group-delay in FM systems) submitted to the LXIII annual meeting of the Italian Electrotechnical Association. (Ischia, 30 September – 6 October 1962, memo 137.)

---

### REPORT 190 \*

#### SUPPRESSION OF AMPLITUDE-MODULATION (CAUSED BY MULTIPATH PROPAGATION) IN FM RECEIVERS

(Question 177(II))

(Los Angeles, 1959 – Geneva, 1963)

1. Contributions relating to Question 177 (II) have been received in Docs. II/8 (Italy) and II/22 (United Kingdom) of Geneva, 1958; Doc. 212 (P. R. of Poland) of Los Angeles, 1959, and Docs. II/19 (P. R. of Poland), II/22 (Japan) and II/28 (United Kingdom) of Geneva, 1962.

#### 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 c/s is preferable for frequency modulation and a value of 100 c/s is recommended. The frequency used for amplitude modulation is preferably 1000 c/s.

- 2.2.2 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 c/s and 3000 c/s with little attenuation.

A band-pass filter, with cut-off frequencies of 900 and 1100 c/s may also be used.

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

---

\* This Report, which replaces Report 103, was adopted unanimously.

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

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

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

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 kc/s 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 AM 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 kc/s

3.2 Doc. II/22 (Japan) of Geneva 1962, gives the following data, measured at 470 Mc/s on transmissions over paths in city and hilly terrain where, due to multipath propagation, a maximum path difference of 150  $\mu$ s and minimum amplitude ratio of 10 db were observed between direct and indirect signal;

<i>AM suppression ratio (db)</i>	<i>Distortion (%)</i>
> 40	< 3
35	4
30	7
25	9

If a professional high-fidelity FM receiver with less than 2% distortion is required, these results indicate that an AM suppression ratio of more than 40 db is required under severe multipath conditions.

3.3 Doc. II/28 (United Kingdom) of Geneva 1962, gives results of measurements made using frequencies of 120 c/s and 2000 c/s, showing the difference obtained between tuning for maximum output power at audio-frequency and tuning for maximum AM suppression. A check was made using frequencies of 100 c/s and 1000 c/s 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.

## REPORT 191 \*

## TOLERABLE RECEIVER TUNING INSTABILITY

(Question 173(II))

(Los Angeles, 1959 – Geneva, 1963)

Two documents—Doc. II/2 (Federal Republic of Germany) and II/24 (United Kingdom)—concerning § 4 of Question 173 (II), were submitted to the 1958 Geneva interim meetings. In particular, Doc. II/24 gives a table listing the required stabilities for different kinds of receiver.

A systematic study of permissible instability seems desirable, on the basis of the documentation already available: Appendix 3 to the Radio Regulations, Geneva, 1959, on transmitter frequency stabilization, Recommendation 332 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  $\pm 10$  c/s (i.e.  $\pm 0.5 \times 10^{-6}$  at 20 Mc/s) 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) of 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 “mark” to “space”.)

---

\* This Report, which replaces Report 100, was adopted unanimously.

TABLE I

Class of emission	Service	Range	Typical frequency (Mc/s)	Fractional frequency tolerance of the transmitter App. 3, R.R. ( $\times 10^{-9}$ ) (%)	Bandwidth at 6 db (Rec. 332) (kc/s) (%)	Man measured value of stability (Rec. 333)		Value proposed for the maximum permissible receiver drift from the typical frequency (%)		Time during which the stability in column 8 is required (hours)	Remarks
						( $\times 10^{-9}$ ) (%) (7a)	Times between which drift was measured (after switching on) (mins) (%) (7b)	Drift (kc/s) (8a)	Relative drift ( $\times 10^{-9}$ ) (8b)		
(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(8a)	(8b)	(9)	(10)
A3	Broadcasting	MF	1	10	5.5	170	10-120	1	1000	2	
		HF	20	15	8	80	10-120	1	50	2	
F3	Broadcasting	VHF	100	20		220	10-120	15	150	2	
A5 (405 lines)	Broadcasting	Band I Band III	50	50		300	10-120	100	2000	2	
			200	50		300	10-120	100	500	2	
A3B	Fixed telephony	HF	20	15	6.5			0.01	0.5	10	Crystal <sup>(4)</sup> or a.f.c.
A3 (50 kc/s 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 (50 kc/s between channels) $\Delta f = \pm 15$ kc/s	Mobile telephony	VHF	160	20	35	5	10-120	5	30		
A1	Fixed telegraphy	LF	0.1	1000	0.2 <sup>(3)</sup>			0.02	200	10	Crystal <sup>(4)</sup> or a.f.c.
		HF	20	50	0.4			0.05	2.5	10	
F1	Fixed telegraphy	HF	20	50				0.01	0.5	10	Crystal <sup>(4)</sup> 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.

(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 \*

TUNING STABILITY OF RECEIVERS

Stability of intermediate-frequency amplifiers with electro-mechanical filters,  
semi-conductor capacitors and ferromagnetic tuning

(Questions 230(II) and 231(II))

(Los Angeles, 1959 – Geneva, 1963)

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.
  - 1.2 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 .
  - 1.3 It is of great interest to determine the characteristic values of tuning stability of receivers having the above-mentioned elements.
2. Some documents have been submitted to the IXth Plenary Assembly of the C.C.I.R., which give some information on this subject (Docs. 110, 121, 123 and 137 (U.S.S.R.) of Los Angeles, 1959).
3. According to the preliminary information received:
  - 3.1 the coefficient of temperature dependence on frequency, for electro-mechanical filters, is of the order  $2 \times 10^{-6}$  to  $5 \times 10^{-6}$ ;
  - 3.2 the temperature stability of filters, with semi-conductor diodes and transistors used as capacitors, might not be worse than the stability of filters using ordinary capacitors and there are ways of improving it;
  - 3.3 the temperature stability of filters with ferromagnetic tuning is at present worse than that of other types of filters with conventional coils.
4. Doc. II/14 (U.S.S.R.) of 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.
  - 4.1 For intermediate-frequency filters with four circuits at 215 kc/s, 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 c/s in a year.
  - 4.2 For crystal filters, having a passband of 0.5 kc/s at a frequency of 150 kc/s, the overall variation of the central frequency is approximately 40 c/s at the end of a year. The ageing factor, measured separately, is responsible for half that instability (20 c/s).
  - 4.3 The lack of stability of filters with a passband of 3 kc/s at the same frequency, when potassium tartrate filters are used, amounts to 200 c/s, not taking account of the effects of ageing.
5. Because of insufficiency of information, further study is considered necessary and forms the subject of Questions 230(II) and 231(II).

---

\* This Report, which replaces Report 101, was adopted unanimously.

## REPORT 193 \*

## SPURIOUS EMISSIONS FROM RECEIVERS

(Question 231(II))

(Los Angeles, 1959 – Geneva, 1963)

## 1. Broadcast and television receivers

- 1.1 In Doc. II/37 (C.I.S.P.R.) of Geneva 1962, the C.I.S.P.R. states that, in its Recommendation 24, it has established the limits for the terminal voltage measurement of television receiver time-base interference, and for radiation from the local oscillators of television receivers and FM broadcast receivers.
- 1.2 Doc. 275 (Italy) of 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). To assist comparison with the

TABLE I

Channel	Radiated frequency (Mc/s)	Polarization	Local oscillator radiation (db rel. 1 $\mu$ V/m)			FCC limits		Number of receivers tested
						$\times 10$ ( $\mu$ V/m)	+20 db (db rel. 1 $\mu$ V/m)	
A	99.5	H V	Max.	Mean	Min.	500	54	11 11
			72.0 58.0	54.5 51.5	42.9 41.6			
B	108	H V	81.4	57.8	47.9	500	54	10 10
			74.9	52.4	40.8			
C	128	H V	81.9	58.6	42.9	500	54	9 9
			77.9	54.4	44.6			
D	221	H V	78.0	65.5	56.5	1500	64	9 9
			73.0	59.6	46.5			
E	229	H V	80.3	65.6	55.3	1500	64	10 10
			77.3	61.4	52.3			
F	238	H V	82.7	66.6	59.7	1500	64	9 9
			78.7	61.5	51.5			
G	247	H V	81.5	65.2	55.0	500	64	9 9
			77.5	61.5	54.0			
H	256	H V	83.2	67.8	56.3	1500	64	10 10
			82.2	65.7	57.1			
A II	199	H V	60.1	38.9	( <sup>1</sup> )	1500	64	11
			53.1	32.7	( <sup>1</sup> )	1500	64	11
B II	216	H V	55.4	41.3	( <sup>1</sup> )	1500	64	11 11
			51.4	27.7	( <sup>1</sup> )			

(<sup>1</sup>) Not given, too low to be measured, due to noise.

\* This Report, which replaces Report 102, was adopted unanimously.

Channel	Radiated frequency (Mc/s)	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)	
F II	476	H V	Max. 77.2	Mean. 64.3	Min. 53.6	5000 <sup>(2)</sup>	74	9
			76.2	61.4	48.6			9
G II	494	H V	83.2	65.6	54.2	5000 <sup>(2)</sup>	74	11
			76.2	64.3	55.2			11
H II	512	H V	77.0	66.7	59.4	5000 <sup>(2)</sup>	74	12
			74.7	65.6	56.5			12
C IV	512	H V	56.5	51.9	45.5	5000 <sup>(2)</sup>	74	12
			57.5	49.3	39.1			12
A V	497.5	H V	56.7	48.1	34.0	5000 <sup>(2)</sup>	74	11
			57.1	46.5	29.5			11
B V	540	H V	58.0	49.0	34.0	5000 <sup>(2)</sup>	74	12
			54.0	46.0	26.0			12
21	510	H V	63.5	52.1	( <sup>1</sup> )	5000 <sup>(2)</sup>	74	12
			62.5	50.7	( <sup>1</sup> )			12
33	610	H V	72.0	52.2	( <sup>1</sup> )	5000 <sup>(2)</sup>	74	7
			69.5	48.8	( <sup>1</sup> )			7

(<sup>1</sup>) Not given, too low to be measured, due to noise.  
 (<sup>2</sup>) Was temporarily relaxed to 10 000 μV/m until 30 April, 1964.

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) ( <sup>1</sup> )	
	Channel 2-6 (54-88 Mc/s)	Channel 7-13 (174-216 Mc/s)	Channel 14-83 (470-890 Mc/s)	450-1600 kc/s	4500 kc/s
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) ( <sup>2</sup> )	100	100

(<sup>1</sup>) Measured in accordance with IRE Standards.  
 (<sup>2</sup>) Was temporarily relaxed to 1000 μV/m until 30 April, 1964.

- 1.3 Doc. II/31 (U.S.A.) of 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/37 (C.I.S.P.R.) of Geneva, 1962, the C.I.S.P.R. states that it has set up a working group to determine whether the methods specified by the I.E.C. in its Publication 106, which it has already accepted, can be applied to receivers other than those used in broadcasting or television.

### 2.2 High grade HF (Band 7) communication receivers

Examination of Doc. II/7 (Italy) of 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 this case, 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) of 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  $0.1 \mu\text{V/m}$  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 aerial 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  $4 \times 10^{-10}$  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 Mc/s and the land mobile services operate in the ranges 71.5 to 88 Mc/s, 156 to 174 Mc/s and 450 to 470 Mc/s. 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  $0.02 \mu\text{W}$  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 229(II))

(Geneva, 1963)

Docs. 18 and 141 (Belgium) of 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.

---

\* This Report was adopted unanimously.  
\*\* Revue HF (High Frequency), 5, 8 (1962).

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

## STUDY GROUP II (Receivers)

### *Terms of reference :*

The selection and study of the more important characteristics of the various types of receivers. Measurement of these characteristics of receivers and tabulation of typical values for the different classes of emission and the different services. Investigations of improvement that might be made in receivers to solve problems encountered in radiocommunication.

*Chairman :* Mr. P. DAVID (France)

*Vice-Chairman :* Mr. Y. PLACE (France)

---

### INTRODUCTION BY THE CHAIRMAN, STUDY GROUP II

1. To understand the work of Study Group II, it must be borne in mind that the term " receiver " covers a variety of devices, ranging from the transistorized pocket receiver to highly complex " triple diversity " and multi-channel apparatus. It also involves many different types of signal: aural telegraphy, or automatic-printing telegraphy; telephony, speech, music; still pictures, charts, photographs; moving pictures, television, and so on. Lastly, such signals can be transmitted by various types of modulation; amplitude-modulation, frequency- or phase-modulation, or pulse-modulation.

The necessity of dealing with so wide a range has led Study Group II (during six Plenary Assemblies and two interim meetings), to build up progressively, a complex set of Recommendations, Reports, Questions and Study Programmes. There has never been time to bring into order the assembled data or to produce an overall report. Hence, a reader, unfamiliar with the work of the C.C.I.R., may have some difficulty in finding his way through a mass of texts, whose basic conceptions and mutual interdependence are not always sufficiently clear.

The object of this introduction, therefore, is to guide the reader in his use of these texts.

2. The first step was to decide what parameters would permit a definition of receiver performance. Three were chosen as basic: sensitivity, selectivity, and stability.

It was then necessary to establish methods for the measurement of these parameters, so that the results obtained should be compatible.

As they were received, the data provided by Administrations were arranged in Tables, by categories, sometimes with indications of statistical values (maximum, mean, minimum).

We then gave thought as to how performance might be improved, and were able to give advice as to the choice of components, lay-out, etc.

Lastly, certain particular cases were selected for special examination.

3. **Sensitivity**

This measures the ability of the receiver to receive weak signals and reproduce them with adequate intensity and acceptable quality. But various cases may arise:

- 3.1 If the amplification is low, the sensitivity will be limited by the strength of the output signal (and not by noise or distortion); it is called " amplification-limited ".
- 3.2 If there is over-amplification, as happens with the majority of modern high-quality receivers, the output level can always be made adequate, but the weak signals will be mixed with distortion or noise, so that reception will be disagreeable, or subject to errors. In this event, " maximum usable sensitivity, limited by noise or distortion " must be defined.

Lastly, since no general agreement has been reached as to acceptable limits for signal-to-noise ratio, distortion, or error rate, it has become necessary to introduce intermediate parameters, such as "reference sensitivity" and "noise factor", for use in measurement, from which the actual performance can be deduced.

Recommendation 331 explains the problem in general terms. The classification of receivers is given in Annex I. The relation between the actual sensitivity and the noise factor, and the relevant formulae, are given in Annex II. Some values of the noise factor are shown in Annex III. The tables in Annex IV (radiotelegraphy, radiotelephony, broadcasting), Annex V (automatic telegraphy, fixed services), Annex VI (FM broadcasting), and Annex VII (television), contain numerous figures of sensitivity and noise factor.

Report 183 deals with sensitivity in the presence of quasi-impulsive interference, and Question 228 (II) shows the points still to be considered.

All these texts were revised and brought up to date at the Xth Plenary Assembly, Geneva, 1963.

#### 4. Selectivity

This measures the capacity of the receiver to select a wanted signal, while eliminating unwanted signals.

It depends on three factors:

- the width of the passband;
- the "slope at the limits of the response curve" (measured by the "single-signal" method);
- and, when interference is powerful, the appearance of beats, intermodulation, and other disturbing effects due to non-linearity of the first stages. These defects can be revealed only by the "multiple-signal" method.

In superheterodyne receivers, image-frequency and IF interference must also be studied.

A last point to note is, that the selectivity affects the phase/frequency characteristic, and hence the group-delay and the shape of the transients. This may cause appreciable distortion, both in telegraphy and television.

Recommendation 332 discusses these problems in general terms, and gives the appropriate definitions. Thereafter, numerous tables set forth the information acquired: Annex I, for telegraphy, telephony and broadcast receivers; Annex II for television; Annex III for frequency-modulation. Annex IV contains some figures for group-delay in telegraph receivers.

Certain non-linear effects of a higher order are described in Report 185. Other special points are discussed:

- methods of measurement using multiple signal (Report 186);
- choice of intermediate-frequency (Report 183);
- protection against keyed interfering signals (Report 187);
- protection of frequency-modulation reception against AM or FM mobile stations (Report 194);
- suppression of amplitude-modulation (due to multipath propagation) in receivers (Report 190);
- methods of measuring phase/frequency or group-delay/frequency characteristics (Report 189).

The C.I.S.P.R. is asked to help in the study of quasi-impulsive interference (Recommendation 334).

Lastly, the points still outstanding are set forth in Question 229 (II).

#### 5. Stability

This is the degree to which the receiver retains its performance with time, despite variations in temperature, power supply voltages, etc.

In superheterodyne receivers, the chief cause of instability is drift of the first local frequency-change oscillator, causing a loss of sensitivity and selectivity, and distortion of the

wanted signal. But this drift can be remedied by slight retuning, or by an automatic tuning device.

Disturbance, more difficult to correct, may be caused by instability of switches, selective filters, and so on.

Recommendation 333 studies this matter in a general way. In its Annex, typical figures for stability are given, assembled in various countries, and for various types of receiver. Other figures are given in Report 191.

Report 188 discusses "tuning criteria", and Report 192 draws attention to the stability of electromechanical filters, semi-conductor capacitors, and ferromagnetic tuning circuits.

Questions 230(II) and 231(II) list those studies which are still considered to be necessary in connection with the measurement of instability and its acceptable limits.

## 6. Miscellaneous

Recommendation 330 and Recommendation 237 refer to the methods devised by the International Electrotechnical Commission for testing broadcasting and television receivers.

Similarly, for spurious re-radiation from these receivers (Recommendation 239), although Report 193 gives some new results supplied direct to the C.C.I.R.

Lastly, at the request of several Administrations, a new and important subject has been approached: the assessment of the minimum and mean (or median) performances of typical receivers, for purposes of standard comparison. Study Programme 185 (II) was drawn up by a special Working Party, which has worked, and will continue to work, by correspondence.

---

## QUESTION 175(II) \*

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

The C.C.I.R.,

(London, 1953 – Warsaw, 1956 – Los Angeles, 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), 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);
- (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, and to calculate the susceptibility of telegraphic receivers subjected to such interference;
2. is it possible to extend these methods to other types of receivers, 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;
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 those 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 as soon as possible to the C.I.S.P.R.

---

\* This Question replaces Question 125.

QUESTION 176(II) \*

**SPURIOUS EMISSIONS FROM RECEIVERS  
EXCLUDING SOUND-BROADCAST AND TELEVISION**

The C.C.I.R.,

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

CONSIDERING

- (a) that many receivers, excluding special types such as high grade HF long distance communication receivers (see Report 193), produce spurious radiation which may harmfully interfere with different services;
- (b) that the I.E.C. lays down measurement methods 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 receivers, 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 receivers; if not, what methods should be used;
3. what are typical values for fields in the different bands and, possibly, for different types of services, that should not be exceeded by these undesired emissions;
4. what are the best techniques to reduce these fields?

---

QUESTION 177(II) \*\*\*

**DISTORTION IN FREQUENCY-MODULATION RECEIVERS  
DUE TO MULTIPATH PROPAGATION**

The C.C.I.R.,

(Warsaw, 1956 – Los Angeles, 1959)

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

---

\* This Question replaces Question 126.

\*\* I.E.C. Publication 106.

\*\*\* This Question replaces Question 127.

- 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 No. 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, 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 direct and indirect signals?

---

## QUESTION 225 (II)

### DIVERSITY RECEPTION UNDER CONDITIONS OF MULTIPATH PROPAGATION

(1962)

The C.C.I.R.,

CONSIDERING

- (a) that multipath propagation is one of the major factors causing distortion of received signals;
- (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;

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 228(II) \*

SENSITIVITY AND NOISE FACTOR

The C.C.I.R., (Stockholm, 1948 – Geneva, 1951 – London, 1953 – Warsaw, 1956 –  
Los Angeles, 1959 – Geneva, 1963)

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 I of Recommendation 331;
  - 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;
  - to determine the input signal necessary 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;

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 \*\*\*;
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:
  - signal distortion, mutilation or element error-rate \*\*\*\*,
  - character error-rate in the reproduced text? \*\*\*\*

\* This Question replaces Question 172.

\*\* For sound broadcast receivers see Recommendation 237.

\*\*\* See Recommendation 331 (Annexes IV and VI).

\*\*\*\* Using, for example:

- the Q9S code (C.C.I.T.T. Recommendation R.51, Volume III)
- the standard synchronized arrangement for Q9S-text (idem)
- a noise-keyed generator.

## QUESTION 229(II) \*

## SELECTIVITY OF RECEIVERS

The C.C.I.R., (Geneva, 1951 – London, 1953 – Warsaw, 1956 – Los Angeles, 1959 –  
Geneva, 1963)

## 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 been chiefly 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 usual selectivity curve (amplitude/frequency characteristic), is insufficient and that other characteristics 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  $2F_n' - F_n''$ , can be calculated one from the other as far as the frequency-differences between  $F_n'$ ,  $F_n''$  and  $F_d$  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.

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are representative figures for the single-signal selectivity of types of receivers, for classes of emission other than A1, A2 and A3;
2. what are the representative figures for interference in frequency-multiplex-systems (especially radiotelegraphy), with 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 receivers, including those for class A1, A2, A3, F1 and F3 signals;
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  $(2F_n' - F_n'')$ ?

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.) of Los Angeles, 1959.

\* This Question replaces Question 178.

\*\* Doc. 109 of Los Angeles, 1959 contains some opinions on this point.

QUESTION 230(II) \*

TUNING STABILITY OF RECEIVERS

The C.C.I.R., (London, 1953 – Warsaw, 1956 – Los Angeles, 1959 – Geneva, 1963)

CONSIDERING

- (a) that the values collected \*\* on tuning stability 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;
- (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.

---

\* This Question replaces Question 173.

\*\* See Recommendation 333.

\*\*\* Some information is available in Doc. II/5 (Federal Republic of Germany) of Geneva 1962.

## QUESTION 231(II) \*

## ASSESSMENT OF STABILITY OF A RECEIVER

The C.C.I.R.,

(Los Angeles, 1959 – Geneva, 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? \*\*

## STUDY PROGRAMME 127(II) \*\*\*

## PROTECTION AGAINST KEYED INTERFERING SIGNALS

The C.C.I.R.,

(Geneva, 1951 – London, 1953 – Los Angeles, 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);
  - the receiver, by increasing the selectivity in regular operation (reduction of bandwidth and increase of slope on each side of the passband) (Recommendation 332).

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; 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;

\* This Question replaces Question 174.

\*\* See § 5.1 of Annex III to Doc. 130 (Sweden) of Geneva, 1963.

\*\*\* This Study Programme replaces Study Programme 43. It does not refer to any Question under study.

- (e) that, for instance, Recommendation 328 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 distortions 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;
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 sensitivity measurements in Recommendation 331 (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 at 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) of London, 1953, 2 (Netherlands), 9 (Belgium), 319 (Japan) and 174 (France) of Warsaw, 1956 and I/31 (United States of America) of Geneva, 1958.

It notes also, that there is a connection between this subject, Report 178 and Study Programme 3A (III).

## STUDY PROGRAMME 185(II) \*

## TYPICAL RECEIVERS

The C.C.I.R.,

(Geneva, 1963)

## 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;
- (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, § 8 of the Interim Report of the Group 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:

1. to determine, for all categories of receivers \*\*, the values of characteristics corresponding to a typical receiver. The values are of two kinds:

1.1 *Typical values*

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 arithmetic *mean* values. 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.

1.2 *Minimum values*

Minimum values are those which should be considered as the limiting values that give an acceptable performance. Some minimum characteristics of certain categories of receivers are the subject of national or international specifications.

- 1.3 In some instances (for example, fixed service receivers), the typical values, which are usually better than the minimum values, may be very close to or even identical with the minimum values.

---

\* This Study Programme does not refer to any Question under study.

\*\* Administrations should give their attention first to receivers for fixed and mobile services, broadcasting and television; subsequently, studies should be carried out on receivers for special services, e.g. for radio-location and radionavigation.

## ANNEX

1. The Annex to this Study Programme is given in the form of Tables, an example of which is Table 5.1.

For economy in space, the complete list of characteristics and the heads of the vertical columns of the tables are given separately in 3 and 4 of the Annex.

2. The various categories of receiver are given at the heads of the vertical columns of the tables.

Numbers, representing the corresponding numbers of the lines representing the different characteristics of the various categories of receiver, have been inserted in the horizontal spaces of the Tables. Certain characteristics, which are of but minor importance for certain categories of receiver, are not indicated in the corresponding Tables.

Each list of characteristics is accompanied by explanatory notes.

### 3. Fixed and mobile services

#### 3.1 List of characteristics

#### 3.2 Notes for the lines of the characteristics table

- |                         |  |
|-------------------------|--|
| Line A1:                | See § 1 and § 4.1 of Recommendation 332.   |
| Line A6:                | See § 4.3 of Recommendation 332.   |
| Line A7:                | See § 4.4 of Recommendation 332.   |
| Line A8:                | See § 4.5 of Recommendation 332.   |
| Lines A9 to A12:        | These points are to be considered only for receivers for the reception of automatic telegraphy which have a passband comparable with the necessary bandwidth (see Recommendation 328).                             |
| Line B1:                | Channel spacing in services with regular channel spacing.  |
| Lines B2 to B5:         | See § 6.2 of Recommendation 332.   |
| Lines B6 to B8:         | See § 6.3 of Recommendation 332.   |
| Lines C2 to C16:        | See § 6.4 of Recommendation 332, except § 6.4.5.   |
| Lines C2, C3 and C4:    | The frequency $F_n'$ should be chosen to keep the difference $F_n' - F_{if}/2$ small.  |
| Lines C5, C6 and C7:    | The frequency $F_n''$ should be chosen to keep the difference $F_n'' - F_d$ small.   |
| Lines C8, C9 and C10:   | The frequency $F_n'$ should be chosen to keep the difference $F_n' - F_d/2$ small.   |
| Lines C11, C12 and C13: | The frequency $F_n''$ should be chosen to keep the difference $F_n'' - F_d$ small.   |
| Lines C14, C15 and C16: | The frequency $F_n'$ should be chosen in order to keep the difference $F_n' - F_d$ small.  |
| Line D1:                | See § 2 of Recommendation 331.   |
| Line D3:                | See § 4 of Recommendation 331 or $\mu\text{V/m}$ for receivers with built-in antenna (e. g. portable receivers).   |
| Lines D7, D8 and D9:    | See § 9.1 and § 5.4 of Annex II of Recommendation 331. It will be necessary to standardize the appropriate text for this test.   |
| Line E1:                | Other types of instability may be considered, particularly for the mobile service (see Report 192 and Annex III to Doc. 130 (Sweden) of Geneva, 1963).   |
| Line F5:                | The diversity characteristic is the difference, in db, required at the input to the receivers in diversity connection, to obtain a reduction at the output, of the weaker signal 30 db below that of the stronger. |

#### 3.3 Types of receivers

See Tables 3.3.1 to 3.3.20.

		Characteristics	
Selectivity	Single-signal selectivity	A1. Passband (kc/s) A2. Bandwidth at 26 db (kc/s) A3. Bandwidth at 46 db (kc/s) A4. Bandwidth at 66 db (kc/s) A5. Bandwidth at 86 db (kc/s) A6. Image attenuation (db) A7. IF attenuation (db) A8. Other spurious responses (db) A9. Group delay time at centre frequency (ms) A10. Maximum deviation of group-delay time (ms) A11. Within the bandwidth specified A12. by attenuation (db) of	{ 3 6 12
	Two-signal selectivity	B1. $F_d - F_n$ (kc/s) B2. (Blocking) Desensitization of 3 db B3. } B4. } Level of unwanted signal (db) for level of wanted signal B5. } (db) of B6. Cross modulation of 20 db B7. Level of unwanted signal (db) B8. for level of wanted signal (db) of	{ 0 20 40 60 20 40 60
	Three-signal selectivity	C1. Wanted frequency $F_d$ (Mc/s) C2. } C3. } C4. } C5. } C6. } C7. } C8. } Intermodulation: level of unwanted C9. } signal (db) for level of wanted C10. } signal (db) of C11. } C12. } C13. } C14. } C15. } C16. }	$\left\{ \begin{array}{l} F_n' + F_n'' = F_{if} \\ F_n' - F_n'' = F_{if} \\ F_n' + F_n'' = F_d \\ F_n' - F_n'' = F_d \\ 2F_n' - F_n'' = F_d \end{array} \right. \left\{ \begin{array}{l} 20 \\ 40 \\ 60 \\ 20 \\ 40 \\ 60 \\ 20 \\ 40 \\ 60 \\ 20 \\ 40 \\ 60 \end{array} \right.$
Sensitivity	Common	D1. Noise factor D2. Post detection bandwidth (kc/s for 3 db)	
	Telephony	D3. Sensitivity (db rel. to 1 $\mu$ V) D4. Signal-to-noise ratio (db) D5. Modulation (%) D6. Maximum frequency deviation (kc/s)	
	Telegraphy	D7. Distortion or mutilation (D or M) D8. } D9. } Sensitivity for an element error-rate of D10. Frequency shift (c/s) D11. Keying speed (Bauds) D12. Automatic gain control (a.g.c.)	{ 1/1000 1/10000
Stability		E1. Tuning stability	
Miscellaneous		F1. Input (balanced or unbalanced) F2. Nominal impedance ( $\Omega$ ) F3. Balance ratio (db) F4. Spurious radiation F5. Diversity characteristics	





3.3.7 Maritime mobile service – Mobile station receivers – Band 10 – 525 kc/s

Characteristics	Facsimile				General purpose			
	A4		F4		A1 Aural		A2 Aural	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 – A4, A6 – A8, B1 – B8, C14 – C16, D1 – D6, D12, E1, F1 – F4								

3.3.8 Maritime mobile service – Coast stations receivers – Band 10 – 525 kc/s

Characteristics	Facsimile				General purpose			
	A4		F4		A1 Aural		A2 Aural	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1–A4, A6–A8, B1–B8, C14–C16, D1–D6, D12, E1, F1–F4								

3.3.9 Maritime mobile service – Mobile station receivers – Bands 1605 – 30 000 kc/s

Characteristics	Tele- graphy	Telephony				Facsimile				General purpose					
	F1	A3		SSB		A4		F4		A1 Aural		A2 Aural		A3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	
A1–A4, A6–A8, B1–B8, C14–C16, D1–D6, D12, E1, F1–F4															



3.3.12 Maritime mobile service – Coast station receivers – Frequencies over 30 Mc/s

Characteristics	Telephony (F3)					
	Outside the bands 156–157.4 and 160.65–162 Mc/s				Bands 156–157.4 and 160.65–162 Mc/s	
	For public network		Not for public network			
	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 – A4, A6 – A8, B1 – B8, C14 – C16, D1 – D6, D12, E1, F1 – F4						

3.3.13 Aeronautical mobile service – Mobile station receivers – Band 200 – 415 kc/s

Characteristics	Telephony		General purpose					
	A3		A1 Aural		A2 Aural		A3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 – A4, A6 – A8, B1 – B8, C14 – C16, D1 – D6, D12, E1, F1 – F4								

3.3.14 Aeronautical mobile service – Aeronautical station receivers – Band 200 – 415 kc/s

Characteristics	Telephony		General purpose					
	A3		A1 Aural		A2 Aural		A3	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1 – A4, A6 – A8, B1 – B8, C14 – C16, D1 – D6, D12, E1, F1 – F4								

3.3.15 *Aeronautical mobile service – Mobile station receivers – Bands 1605 – 30 000 kc/s*

Characteristics	Telegraphy		Telephony						Facsimile				General purpose						
	F1		A3		A3A		A3H		A4		F4		A1 Aural		A2 Aural		A3		
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	
A1–A4, A6–A8, B1–B8, C14–C16, D1–D6, D12, E1, F1–F4																			

3.3.16 *Aeronautical mobile service – Aeronautical station receivers – Bands 1605 – 30 000 kc/s*

Characteristics	Telegraphy		Telephony						Facsimile				General purpose						
	F1		A3		A3A		A3H		A4		F4		A1 Aural		A2 Aural		A3		
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	
A1–A4, A6–A8, B1–B8, C14–C16, D1–D6, D12, E1, F1–F4																			

3.3.17 *Aeronautical mobile service – Frequencies above 30 Mc/s*

Characteristics	Telephony (A3)							
	Mobile stations				Aeronautical stations			
	Except band 100–156 Mc/s		Band 100–156 Mc/s		Except band 100–156 Mc/s		Band 100–156 Mc/s	
	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
A1–A4, A6–A8, B1–B8, C14–C16, D1–D6, D12, E1, F1–F4								



## 4. Monochrome television

## 4.1 Picture Channel

## 4.1.1 List of characteristics

		A1. System
Selectivity	Attenuation (db) for	B1. Adjacent-channel sound (picture) carrier B2. $\mp 1.5$ Mc/s B3. $\mp 1.25$ Mc/s B4. $\mp 1$ Mc/s B5. $\pm 1$ Mc/s B6. $\pm 2$ Mc/s B7. $\pm 3$ Mc/s B8. $\pm 3.5$ Mc/s B9. $\pm 4$ Mc/s B10. $\pm 4.5$ Mc/s B11. $\pm 5$ Mc/s B12. $+ 5.5$ Mc/s B13. $+ 6.5$ Mc/s B14. $+ 7$ Mc/s B15. $+ 11.15$ Mc/s B16. Adjacent-channel picture (sound) carrier
		B17. Group-delay (total spread) (ns) B18. Image frequency attenuation (db) B19. IF attenuation (db) B20. Attenuation of other spurious responses (db)
Sensitivity		C1. Noise factor (db) C2. Gain-limited sensitivity (db) C3. Noise-limited sensitivity (db) C4. Synchronizing sensitivity (db) C5. a.g.c. characteristic (db) C6. Maximum usable input signal level (db)
Stability		D1. } D2. } Frequency drift ( $10^{-6}$ ) during the heating-up periods D3. } (min) D4. } D5. } D6. } Frequency-shift due to variations in the supply voltage D7. } $\left. \begin{array}{l} + 10\% \\ - 10\% \end{array} \right\}$ D8. } Frequency-shift due to change of ambient temperature.../...°C D9. } Frequency-shift due to variations of the input
Distortion		E1. Modulation-frequency response (db) E2. } Unit step response $\left. \begin{array}{l} \text{rise-time (ns)} \\ \text{overshoot (\%)} \end{array} \right\}$ E3. } E4. Low-frequency square-wave response (%)
Miscellaneous		F1. Input circuit (B or U) F2. Nominal input impedance ( $\Omega$ ) F3. Balance ratio (db) F4. F5. F6. F7.

4.1.2 *Notes to Tables of characteristics of monochrome television receivers (picture channel)*

*General*

The procedure to be followed is that recommended by I.E.C. in Publication 107 and its revision.

- Line A1: This line gives the number of lines in the system under consideration and when applicable, in brackets, the video frequency bandwidth.
- Lines B1 to B16: The reference frequency is that corresponding to the picture carrier. Measurements should be made for both positive and negative deviations from the picture carrier.
- Line B17: Difference between the maximum and minimum group-delay variations with frequency for the HF and IF stages of the receiver.
- Lines C2, C3, C4 and C6: Input level in dbm.
- Line C5: Variation in input level (db) for an input level change from -20 dbm to -50 dbm.
- Line D9: For an input variation from -70 dbm to -30 dbm.
- Line E1: The figure represents the maximum difference in db of the response to modulation frequencies comprised between 100 kc/s and the upper nominal video frequency limit.
- Line E2: Time taken to pass from 10% to 90% of the final amplitude of the signal.
- Line E4: Ratio (%), of the step level variation of the response to the front amplitude of that response.
- Line F1: B = balanced, U = unbalanced.

4.2 *Sound channel*

4.2.1 *List of characteristics*

Selectivity	A1.	3 db passband (kc/s)		
	A2.	} Two-signal selectivity for a frequency deviation of (kc/s)	} -400	
	A3.			-300
	A4.			-200
	A5.			-100
	A6.			100
	A7.			200
	A8.			300
	A9.			400
	A10.	Attenuation of other spurious responses (db)		
Sensitivity	B1.	Signal-to-noise ratio		
	B2.	Noise-limited sensitivity		

4.2.2 *Notes to Tables of characteristics of monochrome television receivers (sound channel)*

- Line A1: For AM sound-channel reception.
- Lines A2 to A9: For FM sound-channel reception. Unwanted-to-wanted signal ratio (db), enabling a wanted-to-unwanted signal ratio of 30 db to be obtained at the output for the frequency separations given. The wanted signal level at the input is -40 db (mW).
- Line B2: db in relation to 1 mW at the input.



5. Broadcast receivers

5.1 Table of characteristics (for domestic, portable, pocket and vehicular receivers)

		A3								F3	
		kc/s 150 285		kc/s 525 1605		kc/s 2300 5060		kc/s 5950 26100			
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.		
A1. Receiver category											
Selectivity	Single-signal	B1. passband at 6 db points									
	Two-signal	B2. at $\pm 1 d$ B3. at $\pm 2 d$ B4. at $\pm 4 d$ B5. at $\pm 8 d$ B6. image frequency B7. intermediate frequency (db) B8. at other spurious frequencies (db) B9. at $\pm 1 d$ B10. at $\pm 2 d$ B11. at $\pm 3 d$ B12. at $\pm 4 d$									
Sensitivity		C1. Noise factor (db) C2. Noise-limited sensitivity for a signal-to-noise ratio = 30 db at the output C3. Gain-limited sensitivity for automatic gain-control characteristic (a.g.c.) C4.									
Stability		D1. } Frequency drift { 1 D2. } ( $\times 10^{-6}$ ) during the { 10 D3. } heating-up period { 30 D4. } (min) { 60 D5. } { 120 D6. } Frequency shift { +10% D7. } due to variations { -10% in the supply voltage D8. Frequency shift due to change of ambient temperature .../... °C									
Miscellaneous		E1. Input circuit (B or U) E2. Nominal input impedance (for FM) ( $\Omega$ ) E3. Maximum usable output power (W) E4. Remarks (for example, fidelity)									

*Notes referring to the lines in Table 5.1**General*

The measurement procedure to be followed in all cases is that recommended by the I.E.C. in Publication 69 with the corresponding revisions.

- Lines B2 to B5:  $d = 9$  kc/s (for A3), except where other channel spacings are used.
- Lines B9 to B12:  $d = 9$  kc/s for A3, except where other channel spacings are used and 100 kc/s for F3. Input level of the wanted signal: 30 db above the sensitivity level for F3 and at the sensitivity level for A3. Output level of the wanted signal: 30 db below reference power in both cases.
- Lines C2 and C3: For A3: db rel.  $1 \mu\text{V}$  or db rel.  $1 \mu\text{V/m}$  for receivers with a built-in antenna.  
For F3: db rel. to 1 mW.  
Signal-to-noise ratio 30 db at the output.  
For an output power of 50 or 500 mW.
- Line C4: The figure of merit of the a.g.c. is given by the change in output power (db), for an input level change of 40 to 100 db ( $\mu\text{V}$ ), for A3 reception and of  $-80$  db to  $-20$  db (mW) for F3 receivers, from... to... db ( $\mu\text{V/m}$ ) for receivers with ferrite antennae.
- Lines D1 to D8: May only be significant for receivers with indirectly heated tubes.
- Line E1: B = balanced, U = unbalanced.
- Line E2: For FM only.

6. Spurious emissions from broadcast and television receivers

1					Type or system of receiver				
2 3 4 5 6 7	Frequencies below 30 Mc/s	Injected voltage ( $\mu\text{V}$ )	Into the network	Component	Unbalanced	150 kc/s 500 kc/s 1600 kc/s 4 Mc/s 10 Mc/s 30 Mc/s			
8 9 10 11 12 13					Balanced	150 kc/s 500 kc/s 1600 kc/s 4 Mc/s 10 Mc/s 30 Mc/s			
14 15 16 17 18 19					Into the antenna		150 kc/s 500 kc/s 1600 kc/s 4 Mc/s 10 Mc/s 30 Mc/s		
20 21 22							electric db ( $\mu\text{V}/\text{m}$ )	150 kc/s 500 kc/s 1600 kc/s	
23 24 25					Field-strength (television only)		magnetic db ( $\mu\text{V}/\text{m}$ )	150 kc/s 500 kc/s 1600 kc/s	
26 27 28 29 30 31 32 33 34 35 36							Frequencies above 30 Mc/s	Field-strength (db $\mu\text{V}/\text{m}$ )	

*General Note*

In accordance with I.E.C. Publication 106 and its revisions (see Recommendation 239).

Lines 2 to 36: Approximate radiated frequency.

Lines 23 to 25: In accordance with convention adopted by the I.E.C. (Publication 106).

LIST OF DOCUMENTS OF THE Xth PLENARY ASSEMBLY CONCERNING STUDY GROUP II

Doc.	Origin	Title	Reference	Other Study Groups concerned
2	Chairman, Study Group II	Report by Chairman of Study Group II (Mr. P. David)	—	—
18	Belgium	Interference caused to FM reception by AM and FM VHF mobile stations	—	XIII
91	United States of America	Report on figures of merit for radio receiving systems in the presence of noise or unwanted-signal interference and the concepts of operating noise-factor and operating noise-temperature — Report	Q. 172	IV
105	India	Design and performance of VHF receiving equipment for reception of extremely weak signals of solar and galactic origin in the metre wavelength region	—	IV
129	C.C.I.R. Secretariat	Bibliographic references in the volumes of the C.C.I.R.	—	I-XIV
130	C.C.I.R. Secretariat	Replies to Circular AC/65	Circ. AC/65	—
141	Belgium	Interference to FM reception by emissions from VHF (metric) mobile AM- and FM-stations	Q. 178 Q. 163 (XIII)	XIII
146	Netherlands	Performance of telegraph systems and receivers	Rec. 234 Rep. 105 (III)	III
153	C.C.I.R. Secretariat	Refinement of I.F.R.B. technical standards	—	I, III, V, VI, X, XII, XIII
197	U.S.S.R.	Noise and sensitivity of receivers	Q. 172 (Doc. II/38)	—
216	United Kingdom	Proposed amendments and corrections to Annexes of Doc. 2 (Report by Chairman of Study Group II)	Doc. 2	—
241	P.R. of Poland	Typical monochrome television receivers	Circ. AC/65 (Doc. II/59-Rev.)	XI
264	U.S.S.R.	Clarification of Recommendation 234	Rec. 234	—
268	Italy	The national situation on the measurement of spurious emissions from broadcast and television receivers	Rec. 239	—
275	Italy	Remarks on Doc. 2	Doc. 2	—
292	Study Group II	Summary record of the first meeting	—	—
321	„	Typical receivers	Draft S. P.	—
361	„	Summary record of the second meeting	—	—
464	„	Typical receivers	Draft S. P.	—
488	Sub-Group II-B	Modifications to Annex 2/19	—	—
489	„	Response of broadcast and television receivers to impulsive and quasi-impulsive interference	Draft Rec.	—
490	„	Modifications to Annex 2/2	—	—
491	„	Modifications to Annex 2/1	—	—
516	„	Assessment of stability of a receiver	Draft Q.	—
517	„	Modifications to Annex 2/21	—	—
535	„	Modifications to Docs. 18 and 141	Q. 178	—

Doc.	Origin	Title	Reference	Other Study Groups concerned
547	Sub-Group II-A	Modifications to the Annex of Doc. 321	Doc. 321	—
583	Study Group II	Summary record of the third meeting	—	—
602	Study Group II	Summary record of the fourth and last meeting	—	—
2051	Drafting Committee	Tuning stability of receivers	Rec. 333	—
2052	„ „	Sensitivity, selectivity and stability of television receivers	Rec. 330	—
2053	„ „	Sensitivity and noise factor	Q. 228	—
2054	„ „	Selectivity of receivers	Q. 229	—
2055	„ „	Tuning stability of receivers	Q. 230	—
2056	„ „	Usable sensitivity of radio receivers in the presence of quasi-impulsive interference	Rep. 183	—
2057	„ „	Choice of intermediate frequency and protection against unwanted responses of super-heterodyne receivers	Rep. 184	—
2058	„ „	Selectivity of receivers	Rep. 185	—
2059	„ „	Multiple-signal methods of measuring selectivity	Rep. 186	—
2060	„ „	Protection against keyed interfering signals	Rep. 187	—
2061	„ „	Criteria for receiver tuning	Rep. 188	—
2062	„ „	Methods of measuring phase/frequency or group-delay/frequency characteristics of receivers	Rep. 189	—
2063	„ „	Suppression of amplitude modulation (due to multipath propagation) in FM receivers	Rep. 190	—
2064	„ „	Tuning stability of receivers	Rep. 192	—
2191	„ „	Response of broadcast and television receivers to impulsive and quasi-impulsive interference	Rec. 334	—
2195	„ „	Typical receivers	S. P. 185	—
2230	„ „	Tolerable receiver tuning instability	Rep. 191	—
2231	„ „	Selectivity of receivers	Rec. 332	—
2232	„ „	Noise and sensitivity of receivers	Rec. 331	—
2295	„ „	Typical receivers	S. P. 185	—
2296	„ „	Assessment of stability of a receiver	Q. 231	—
2297	„ „	Spurious emissions from receivers	Rep. 193	—
2298	„ „	Interference caused to FM reception by AM and FM VHF mobile stations	Rep. 194	—

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

RECOMMENDATIONS OF SECTION K: VOCABULARY

RECOMMENDATION 430 \*

UNIT SYSTEMS

(Resolution 6)

The C.C.I.R.,

(London, 1953 – Geneva, 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 17th and 18th 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 \*\*

NOMENCLATURE OF THE FREQUENCY AND WAVELENGTH BANDS  
USED IN RADIOCOMMUNICATIONS

(Question 73)

The C.C.I.R.,

(London, 1953 – Warsaw, 1956 – Los Angeles, 1959 – Geneva, 1963)

CONSIDERING

- (a) that the merits of Heinrich Hertz (1857–1897), as a research worker on the basic phenomena of radio waves, are universally recognized, as was confirmed at the centenary of his birth, and that as early as 1937 the I.E.C. adopted the Hertz (symbol: Hz) as a name for the unit of frequency (see, *inter alia*, the International Electrotechnical Vocabulary, publication 50/05, 1954 edition: 05–35–055, page 44, and 05–35–110, page 47);

---

\* This Recommendation replaces Recommendation 143.

\*\* This Recommendation replaces Recommendation 324.

- (b) that the C.C.I.T.T. also uses the Hertz (cf. Red Book, French version);
- (c) that in this Recommendation the table should be as synoptic as possible and that the expression of frequencies should be as concise as possible;
- (d) that the Administrative Radio Conference, Geneva, 1959, adopted the nomenclature contained in the table given in Recommendation 324 (Los Angeles, 1959), which is reproduced as an Annex to this Recommendation, with the three notes contained in No. 112 of the Radio Regulations, Geneva, 1959 (Note 3 shows the correlation between the designation of the frequency bands by numbers in the new nomenclature and the adjectival designations, VLF, LF, etc., in the previous nomenclature).

## UNANIMOUSLY RECOMMENDS

1. that the Hertz (Hz) be accepted for use, alternatively with cycles per second (c/s), as a 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 subdivision
4	3 to 30 kc/s (kHz)	Myriametric waves
5	30 to 300 kc/s (kHz)	Kilometric waves
6	300 to 3 000 kc/s (kHz)	Hectometric waves
7	3 to 30 Mc/s (MHz)	Decametric waves
8	30 to 300 Mc/s (MHz)	Metric waves
9	300 to 3 000 Mc/s (MHz)	Decimetric waves
10	3 to 30 Gc/s (GHz)	Centimetric waves
11	30 to 300 Gc/s (GHz)	Millimetric waves
12	300 to 3 000 Gc/s (GHz) or 3 Tc/s (THz)	Decimillimetric waves

Note 1. — “Band number N” extends from  $0.3 \times 10^N$  to  $3 \times 10^N$  c/s (Hz).

Note 2. — Abbreviations:

c/s = cycles per second, 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)

(Geneva, 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.) of 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.

---

\* This Report was adopted unanimously.

**PAGE INTENTIONALLY LEFT BLANK**

**PAGE LAISSEE EN BLANC INTENTIONNELLEMENT**

## 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)

## RESOLUTION 21 \*

### TERMS AND DEFINITIONS

The C.C.I.R.,

(Geneva, 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, among the tasks to be accomplished in this respect, by far the most important and also the most difficult is establishing a definitive terminology, and that the I.T.U. Administrative Council has recommended (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 which (general terms, telephony, telegraphy), has been published by the I.T.U. and is now being revised by the C.C.I.T.T. (Study Group VII), and Part II of which, relating to radiocommunications and for which the C.C.I.R. has responsibility, has yet to be prepared;
- (c) that, since its VIth Plenary Assembly, Geneva, 1951 (Recommendation 144), 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 of 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 of Study Group XIV in his Report - Doc. 14 of 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 (cf. Annex to Resolution 62 \*\*), had been or was about to be appointed;

\* This Resolution replaces § 1 of Resolution 62.

\*\* The appropriate sections of the Annex to Resolution 62 are reproduced in Annex II to this Resolution.

## UNANIMOUSLY RESOLVES

1. that the work already started will be continued by correspondence with all possible despatch, in accordance with the programme annexed hereto, by an international Working Group under the guidance of the Chairman of 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. P. DAVID (France), Mr. K. VREDENBREGT (Netherlands), and possibly Mr. LOWRY (United Kingdom);
Study Group III:	Mr. F. THABARD (France), Mr. S. G. YOUNG (United Kingdom);
Study Group IV:	Mr. M. THUE (France), Mr. S. M. MYERS (U.S.A.);
Study Group V:	Mr. L. BOITHIAS (France), Mr. F. HORNER (United Kingdom), and Mr. HERBSTREIT (U.S.A.);
Study Group VI:	Mr. J. VOGÉ (France), Mr. P. A. MORRIS (United Kingdom);
Study Group VII:	Mr. B. DECAUX (France), Mr. J. M. STEELE (United Kingdom);
Study Group VIII:	Mr. .... Mr. ....
Study Group IX:	Mr. J. VERRÉE (France), Mr. ....
Study Group X:	Mr. S. LACHARNAY (France), Mr. G. JACOBS (U.S.A.), and possibly Mr. L. W. TURNER (United Kingdom);
Study Group XI:	Mr. L. GOUSSOT (France), Mr. ....
Study Group XII:	Mr. .... Mr. ....
Study Group XIII:	Mr. J. BES (France), Mr. G. H. M. GLEADLE (United Kingdom);
Study Group C.M.T.T.:	Mr. L. GOUSSOT (France), Mr. ANDERSON (United Kingdom, I.T.A.);

each Study Group Chairman being responsible for appointing persons to complete this list of names and, if necessary, for filling any gaps;

- a “National Collaborator” (see § 1.4 of the Annex to Resolution 62 \*) to be appointed by each of the following Administrations: United States of America (Prof. H.R. MISMO), France, United Kingdom (and, possibly, other countries where work is being done on the vocabulary which would enable them to supply helpful contributions in English and French).

## ANNEX I

## PROGRAMME OF WORK

Each member of the Working Group will find in the Annex to Resolution 62 (Los Angeles, 1959), some general information on the broad outlines of the work and the division of duties.

\* The appropriate sections of the Annex to Resolution 62 are reproduced in Annex II to this Resolution.

If he has not already received one in Geneva, a copy of the basic document (Doc. XIV/1 of 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 Secretariat of the C.C.I.R., who will work together to obtain a coherent aggregate text.

This text will be forwarded to all the members of the Working Group 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 Group, 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 Group, 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 (roneo), 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 of Geneva, 1963 – Terms relating to ARQ systems. The study of this proposal was able to be made in Geneva, in a small “Joint Working Group”, set up by Study Groups III and XIV. The result was deemed sufficiently acceptable to be added as Annex VIII to Recommendation 342, 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 Group, 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.) of 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 Group, a text which could become a complement to the “List”.

For this task, the Working Group 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 of Geneva, 1963, the Secretariat of the C.C.I.R. 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 of 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 Group, 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 of 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 of 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 C.C.I.R. AND OF OTHER ORGANIZATIONS ON UNIFICATION OF MEANS OF EXPRESSION**

The C.C.I.R.,

(Geneva, 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 in Geneva, 1951, at the instigation of the International Federation of Documentation (F.I.D.), has remained in abeyance, without any result other than the unimplemented proposal contained in Report 95 (Warsaw, 1956), issued as a supplement to Report 37 (London, 1953);

UNANIMOUSLY 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 co-operation 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 of Study Group XIV shall jointly assess, according to the urgency of the

---

\* This Resolution replaces § 2 of Resolution 62.

- 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.,

(Geneva, 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 Second 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 of Study Group XIV informed of the progress of the work.

---

LIST OF DOCUMENTS OF THE Xth PLENARY ASSEMBLY CONCERNING STUDY GROUP XIV

Doc.	Origin	Title	Reference	Other Study Groups concerned
14	Chairman, Study Group XIV	Report by Chairman of Study Group XIV (Mr. R. Villeneuve)	—	—
108	United Kingdom	Definition of right and left-handed elliptically or circularly polarized electromagnetic waves	—	IV
121	Netherlands	Terms related to ARQ-systems	Rec. 242 Res. 34	III
129	C.C.I.R. Secretariat	Bibliographic references in the volumes of the C.C.I.R.	—	I-XIV
195	U.S.S.R.	International vocabulary, terms in the reliability theory for radio systems	Res. 62	—
252	France	Terms used in space telecommunications	—	IV
338	Study Group XIV	Summary record of the first meeting	—	—
395	Study Groups I & XIV	Recommendation	Q. 207 (I), § 4	I
479	Study Groups III & XIV	Automatic error correction system for telegraph signals transmitted over radio links	Draft Rec.	III
578	Study Group XIV	Terms and definitions	Draft Res.	—
596	„	General graphical symbols for telecommunication	Draft Res.	—
601	„	Coordination of the work of C.C.I.R. and of other organizations on unification of means of expression	Draft Res.	—
623	„	Draft amendment to Recommendation 143 – Unit systems	Rec. 143	—
624	„	Draft amendment to Recommendation 324 – Nomenclature of the frequency and wavelength bands used in radiocommunications	Rec. 324	—
625	„	Terms and definitions	Draft Rep.	—
636	„	Summary record of the second, third and last meetings	—	—
2257	Drafting Committee	Terminology	Rec. 325	I
2343	„ „	Terms and definitions relating to space radiocommunications	Rep. 204	IV
2360	„ „	General graphical symbols for telecommunication	Res. 23	—
2384	„ „	Terms and definitions	Res. 21	—
2385	„ „	Coordination of the work of C.C.I.R. and of other organizations on unification of means of expression	Res. 22	—
2390	„ „	Unit systems	Rec. 430	—
2391	„ „	Nomenclature of the frequency and wavelength bands used in radiocommunications	Rec. 431	—
2392	„ „	Terms and definitions	Rep. 321	—

PRINTED IN SWITZERLAND