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Methods of measurement for radio transmitters Part 2 : Bandwidth, out-of-band power and power of non-essential oscillations

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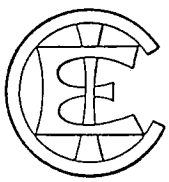

Bureau Central de la Commission Electrotechnique Internationale

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

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FOREWORD

1) The formal decisions or agreements of the I E C on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote this international unification, the I E C expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the I E C recommendations as the fundamental basis for these rules in so far as national conditions will permit.

4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by Sub-Committee 12C, Radio Transmitting Equipment, of IEC Technical Committee No. 12, Radio-communication.

This Recommendation forms Part 2 of a Recommendation which is intended, after its completion, to lay down recommended methods of measurements for radio transmitters for various classes of emission.

Part 2, which shall be used in conjunction with Part 1, IEC Publication 244-1, deals with the measurement of the power of the components, either in the outer part of the emitted spectrum or far remote from the centre part of the spectrum, that may cause interference to other emissions.

Information of a general character, C.C.I.R. Recommendations and Reports, and Articles of the Radio Regulations drawn up by the International Telecommunication Union (I.T.U.) have been added in whole or in part in the appendices of this Recommendation, where it was considered useful to have these references at hand. These appendices are contained in the first supplement to this Recommendation (IEC Publication 244-2A).

Modulating signals, which may be used for measuring the bandwidth and the out-of-band power of emissions for telephony and sound broadcasting, have been laid down in a separate IEC Report. This Report, which is to be considered as an Appendix to Section Two of the Recommendation, is contained in the second supplement to this Recommendation (IEC Publication 244-2B).

It should be realized that the recommended methods of measurement may in due course be subject to improvement or extension; this Recommendation will then be amended or completed.

Several drafts of the Recommendation were discussed at meetings held in Nice in 1962, in Baden in 1963, in Kootwijk in 1964 and in Constanz in 1965. As a result of the meeting held in Tokyo in 1965, a final draft for each section was prepared and submitted to the National Committees for approval under the Six Months' Rule in March 1967.

The following countries voted explicitly in favour of publication of Section One:

Australia	Japan
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United States of America

METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

Part 2 : Bandwidth, out-of-band power and power of non-essential oscillations

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1. Object

The object of this Recommendation is to standardize the conditions and methods of measurement to be used to ascertain the performance of a radio transmitter and to make possible the comparison of the results of measurements made by different observers.

This Recommendation contains details of selected methods of making measurements, recommended for assessing the essential properties of a radio transmitter. The methods of measurement described are restricted to those properties that may be liable to ambiguous interpretation due to the application of different methods and conditions of measurement. They are neither mandatory, nor limiting; a choice of measurements can be made in each particular case. If necessary, additional measurements may be performed, but these shall preferably be carried out in accordance with the standards laid down by other IEC Technical Committees or Sub-Committees, or by other international bodies.

Limiting values of the various quantities for acceptable performance are not specified as these should be given in the relevant equipment specification, preferably in the form laid down in a forthcoming IEC Recommendation.

The methods of measurement detailed in this Recommendation are intended for type tests and may also be used for acceptance tests and factory tests (see Clause 3 of IEC Publication 244-1).

2. Scope

This Recommendation deals with the measurement of the power of the components, either in the outer part of the emitted spectrum or far remote from the centre part of the spectrum, that may cause interference to other emissions. The measuring conditions and methods of measurement apply to transmitters for various classes of emission.

SECTION ONE — TERMS AND DEFINITIONS

3. General notes on the frequency spectrum of an emission

With respect to the subject dealt with in this part of the Recommendation, it is considered useful to draw attention to the following:

3.1 Any information to be transferred may be converted into a periodic or non-periodic oscillation which may be considered as consisting of a number of sinusoidal oscillations forming a frequency spectrum of a certain width.

The width of this spectrum may be limited to some extent, depending on the required quality of the transfer of information. In whole or in part, this is already accomplished by the physical limitations of the conversion process itself, e.g. by the amplitude/frequency characteristic. On the other hand, additional oscillations may appear due to the non-linear properties of the converter, causing unwanted intermodulation and/or harmonic oscillations and thus broadening the width of the spectrum unnecessarily.
By using radio transmitters and receivers as a specific means of transferring information, the above mentioned spectrum is converted into a radio-frequency spectrum. Due to non-linear effects during the relevant processes of modulation and amplification of the radio-frequency oscillations, again unwanted oscillations may appear causing the frequency band occupied by the emission to be larger than necessary. Moreover, additional oscillations may occur which are not essential for the transmission of information, such as harmonics of the frequency of the fundamental oscillation.

As all radio transmitting systems use the propagation of electromagnetic waves in free space as a common means of conveyance, it is of the utmost importance to ensure the maximum economy in this part of the connection and to avoid interference with other radio channels.

For this reason, special regulations based on Recommendations of the C.C.I.R. are drawn up by the International Telecommunication Union and laid down in the Radio Regulations.

These regulations stipulate:

a) The limitations of that part of the spectrum, outside the necessary bandwidth, to a value that is within the tolerance relevant to the class of emission.

This may be achieved by:

— the use of low-pass or band-pass filters at the input side of the transmitter, as for example, a keying filter in a radio-telegraphy transmitter;

— applying suitable coupling circuits and/or special band-pass filters in the radio-frequency part of the transmitter, as for example, a vestigial sideband filter in a television transmitter;

— reducing the degree of non-linearity of the modulator and radio-frequency amplifier stages of the transmitter or by reducing the modulation or utilization factor.

b) The reduction of that part of the radiation of a given emission which is not essential for the transmission of information to within the tolerances relevant to the output power and assigned frequency band of the transmitter.

This may be accomplished by:

— The use of low-pass or other output filters;

— applying suitable coupling circuits;

— screening of various stages of the transmitter, filters and other parts of the equipment, e.g. as described in reference [6] of Appendix A.

3.2 The purpose of the measurements indicated in this part of the Recommendation is to prove, as far as possible, on the basis of the results of measurements made on a transmitter when connected to a test load and operating under specified conditions of modulation, that the transmitter will satisfy the requirements recommended by the C.C.I.R. as laid down in the Radio Regulations, when it will be used in actual traffic under normal operating conditions. However, it should be noted that, unless the impedance and other selective properties of the test load for all frequencies concerned are exactly equal to those of the aerial and its associated transmission line, measurements made under actual conditions do not generally lead to the same results.

The C.C.I.R. Recommendations and the Radio Regulations concern the emissions themselves; the methods of measurement given in this Recommendation, however, are related to radio transmitters and thus the definitions of the various concepts which apply within the province of the I.T.U. and C.C.I.R. cannot be used as they stand. Therefore, it is deemed profitable to use for radio transmitters, definitions derived from those mentioned above, amended to suit this purpose.

3.3 From Sub-clause 3.1, it follows that the concept of bandwidth when related to radio transmitters must be clearly distinguished from the bandwidth of passive networks as commonly used in receiver and amplifier techniques.

The first concept is usually defined as that frequency interval of a frequency spectrum, above and below which the mean powers are each equal to a certain percentage of the total mean power contained in the spectrum; it is evaluated by measuring the individual spectrum components (by methods given in Section Two) when a specified combination of modulating oscillations is applied at the input to the transmitter; for a radiotelephone transmitter, this combination may consist, for example, of the signal produced by a standard voice simulating device, or of flat or shaped random noise.

The second concept of bandwidth is related to the "radio-frequency passband" as defined in Sub-clause 19.2.1 of IEC Publication 244-1. Evaluating the radio-frequency passband, the frequency of the (oscillator) stage determining the carrier or characteristic frequency is gradually changed and the output power measured, without applying any modulation.

Finally, a third concept, the "amplitude/frequency characteristic", must be distinguished from the bandwidth and the radio-frequency passband. The amplitude/frequency characteristic is a measure of the fidelity of the transmission of information and, in this respect, important for the service for which the transmitter is intended. It is evaluated by measuring, either the power of the demodulated signal, or, for amplitude-modulation transmitters, the power of either sideband component (or of one sideband component, if one of the sidebands is suppressed), in both cases gradually changing the frequency of a sinusoidal oscillation with constant amplitude applied at the input to the transmitter. For the determination of the amplitude/frequency characteristics, reference is made to IEC Publication 244-4 (in preparation).

An elucidation of the concepts mentioned above is given in Figure 1, page 62.

4. Definitions

The definitions of Sub-clauses 4.1 and 4.3 to 4.6 below apply to radio transmitters connected to a test load; they have been derived from the sources indicated in the corresponding notes.

An elucidation of the various definitions if given in Figure 2, page 63.

4.1 *Bandwidth*

The frequency interval in the power spectrum, above and below which the mean powers, at the output terminal device of a radio transmitter, under specified conditions of modulation for a given class of emission, are each equal to a certain percentage (Note) of the total mean power contained in the spectrum, the power of non-essential oscillations (see Sub-clause 4.5) at frequencies remote from the limits of the band being excluded.

Note. — Values for the percentage pertaining to various classes of emission are laid down in the Radio Regulations or are recommended by the C.C.I.R.; see reference [1] of Appendix A.

4.2 *Necessary bandwidth*

For a given class of emission, the minimum value of the bandwidth (as defined in Sub-clause 4.1) sufficient to ensure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Spectrum components useful for the good functioning of the receiving equipment as, for example, the component corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.

Note. — This definition is in conformity with the Radio Regulations; see reference [2] of Appendix A.

4.3 *Out-of-band oscillation*

Oscillation at a frequency which is outside the necessary band, with the exception of non-essential oscillations (see Sub-clause 4.5) at frequencies remote from the limits of the necessary band.

Note. — The definition of out-of-band oscillation concerns the oscillations present at the output terminal device of a transmitter; they may give rise to out-of-band radiation (defined in the C.C.I.R. Recommendation reproduced in Appendix B) if the transmitter is connected to an aerial.

4.4 *Out-of-band power*

Sum of the mean powers of all out-of-band oscillations at the output terminal device of a radio transmitter under specified conditions of modulation for a given class of emission.

Notes 1. — See Note to Sub-clause 4.3.

2. — The bandwidth occupied by a given emission, considered perfect from the point of view of spectrum economy, coincides with the necessary bandwidth for the class of emission concerned. In this case, the out-of-band power is equal to the total mean power multiplied by twice the specified percentage mentioned in Sub-clause 4.1.

3. — For transmitters used in channel-spaced systems, as is customary in the land mobile, maritime mobile and aeronautical mobile services, the out-of-band power in the adjacent channel, that is the sum of the mean powers of the out-of-band oscillations contained in that channel, may be specified separately.

4.5 *Non-essential oscillation*

Oscillation at a frequency, or at a narrow band of frequencies, remote from the limits of the necessary band, the level of which may be reduced without affecting the corresponding transmission of information.

A non-essential oscillation may be either:

a) a *harmonic oscillation* at a frequency (or at a narrow band of frequencies) which is a whole multiple of those comprised in the band occupied by the emission;

b) an *unwanted oscillation* at the frequency and harmonics thereof of any oscillation used in the course of generation of the oscillation at the carrier or characteristic frequency * of the emission; or an *unwanted oscillation* at one of the frequencies resulting from intermodulation between these oscillations;

c) a *parasitic oscillation*, accidentally generated at a frequency (or at a narrow band of frequencies) which is independent both of the carrier or characteristic frequency of the emission, and of frequencies of oscillations appearing in the course of generation of the oscillation at the carrier or characteristic frequency; or

* See Sub-clause 8.2 of IEC Publication 244-1 for the definition of the characteristic frequency of an emission.

d) an *external intermodulation component* at one of the frequencies (or *external intermodulation products* in one of the narrow bands of frequencies) resulting from intermodulation between:

— the oscillation at the carrier, characteristic or harmonic frequency of an emission, or the oscillations which appear when the carrier or characteristic frequency is generated,

and:

— oscillations of the same nature, of one or several other emissions, originating from the same transmitting system * or from other transmitters or transmitting systems.

Note. — The above definitions of non-essential oscillations concern the oscillations present at the output terminal device of the transmitter; they may give rise to spurious radiations (defined in the C.C.I.R. Recommendation reproduced in Appendix C) if the transmitter is connected to an aerial.

4.6 *Power of a non-essential oscillation*

Mean power of a non-essential oscillation at the output terminal device of a radio transmitter, or at the common output terminal device of several radio transmitters, under specified conditions of modulation for a given class of emission.

4.7 *Flat random noise*
White noise
Uniform-spectrum random noise

Random noise whose spectral distribution between specified frequency limits is such that the noise power per unit bandwidth is independent of frequency.

4.8 *Shaped random noise*
Coloured noise
Weighted noise

Random noise whose spectral distribution is such that the noise power per unit bandwidth depends on the frequency in a specified way.

Note. — For instance, this dependency may be specified by a curve representing the statistical distribution of power when reproducing a programme of music or conversational speech; see IEC Publication 244-2B, Second Supplement to Publication 244-2.
Another example is noise, weighted according to a psophometric curve. For psophometric curves, reference is made to IEC Publication 244-3 (in preparation).

SECTION TWO — BANDWIDTH AND OUT-OF-BAND POWER

5. General notes on bandwidth and out-of-band radiation

To ascertain that the frequency band occupied by an emission is within the frequency band assigned to the service concerned, the occupied bandwidth and the characteristic frequency of the emission are to be determined, the latter according to the principles given in IEC Publication 244-1.

Apart from this aspect which is related to the radio spectrum economy, the determination of the power of components in the outer parts of the emitted spectrum is necessary because these components may be causing interference to radio channels of neighbouring emissions.

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* See Sub-clause 3.2 of IEC Publication 244-1 for the definition of transmitting systems.

Pertaining to the class of emission, values of necessary bandwidths are laid down in the Radio Regulations (see Appendix E) whilst, in certain cases, limitations of the emitted spectra are recommended by the C.C.I.R. (see Appendix B).

These requirements refer to a transmitter connected to its aerial system. However, measurements performed on a transmitter connected to a test load usually give a reasonably true picture of the characteristics concerned unless, as may occur with transmitters operating in LF and VLF bands, the emitted spectrum is limited to a substantial degree by the selective properties of the aerial and the device for matching the aerial to the transmission line.

In performing such measurements, a standardized modulating signal should be chosen in accordance with the class of emission concerned and simulating, as far as possible, the type of modulation encountered in actual traffic.

6. Conditions of measurement

The transmitter, as defined in Sub-clause 3.1 of IEC Publication 244-1, shall be operated under the following conditions.

6.1 *Conditions of operation*

6.1.1 *General*

The voltage and the frequency of the primary power supply shall be within the tolerances stated in the relevant equipment specification.

The transmitter shall be connected to a test load, as specified in Sub-clause 6.1.2 below.

If these devices are covered in the relevant equipment specification, auxiliary equipment such as a band limiting filter at the modulation input side, a limiting amplifier, a clipper, a device for automatic load control or any combination of this equipment, shall be operative.

Before making measurements, it is recommended that other requirements quoted in the relevant equipment specification (e.g. with regard to the non-linearity distortion of radiotelephone transmitters and to the telegraph distortion of radiotelegraph transmitters) have been satisfied.

6.1.2 *Terminal load*

Referring particularly to:

1) low-powered transmitters in which direct connection to the aerial is made; and
2) long-wave and medium-wave transmitters using a separate device to match the aerial to the transmitter,

it should be noted that the transfer properties of the matching network and the aerial as well as the resistive and reactive components of impedance presented to the output terminals of the transmitter may vary considerably over the frequency band occupied.

Hence, the bandwidth and the out-of-band power depend on the characteristics of the aerial matching network and the aerial itself and the following cases are therefore to be taken into account with respect to the choice of the characteristics of the test load.

a) If an aerial matching network is incorporated in the transmitter or if a separate matching network covered by the relevant equipment specification is available, this device shall be in operation between the transmitter and the test load.
In either case, the test load has to replace the aerial and shall meet the requirements relevant to the impedance of the aerial quoted in the equipment specification.