

Specification for radio disturbance and immunity measuring apparatus and methods —

Part 1: Radio disturbance and immunity measuring apparatus

ICS 17.220.20; 33.100.10; 33.100.20

National foreword

This British Standard reproduces verbatim CISPR 16-1:1999, Edition 2.1:2002, which comprises Edition 2.0:1999 consolidated by the incorporation of amendments 1:2002 and 2:2003, and implements it as the UK national standard. It supersedes BS CISPR 16-1:1998 which is withdrawn.

BS 727:1983 which is related to CISPR 16:1987 is not being withdrawn as it is referred to in Statutory Instruments which HM Government does not propose to amend at this time.

The UK participation in its preparation was entrusted to Technical Committee GEL/210/12, EMC — Basic and generic standards, which has the responsibility to:

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COMITÉ INTERNATIONAL SPÉCIAL DES PERTURBATIONS RADIOÉLECTRIQUES
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**Spécifications des méthodes et des appareils
de mesure des perturbations radioélectriques et
de l'immunité aux perturbations radioélectriques –**

Partie 1:

**Appareils de mesure des perturbations
radioélectriques et de l'immunité aux
perturbations radioélectriques**

**Specification for radio disturbance and
immunity measuring apparatus and methods –**

Part 1:

**Radio disturbance and immunity
measuring apparatus**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY
MEASURING APPARATUS AND METHODS –**

Part 1: Radio disturbance and immunity measuring apparatus

FOREWORD

- 1) The formal decisions or agreements of the CISPR on technical matters, prepared by subcommittees on which all the National Committees and other Member Organizations of the CISPR having a special interest therein are represented, express, as nearly as possible, an international consensus on the subjects dealt with.
- 2) They have the form of recommendations for international use and they are accepted by the National Committees and other Member Organizations of the CISPR in that sense.
- 3) In order to promote international unification, the CISPR expresses the wish that all National Committees should adopt the text of the CISPR recommendations for their national rules in so far as national conditions will permit. Any divergence between the CISPR recommendations and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This publication has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

This consolidated version of CISPR 16-1 is based on the second edition (1999) [documents CISPR/A/244/FDIS and CISPR/A/254/RVD] and its amendment 1 (2002) [documents CISPR/A/374/FDIS and CISPR/A/395/RVD].

It bears the edition number 2.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

Annexes A, B, C, D, E, F, G, H, O, P, Q and X form an integral part of this CISPR publication.

Annexes I, J, K, L, M, N, R, S, T, U, V and W are for information only.

The committee has decided that the contents of the base publication and its amendment 1 will remain unchanged until 2003. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 1: Radio disturbance and immunity measuring apparatus

1 Scope

This part of CISPR 16 is designated a basic standard, which specifies the characteristics and performance of equipment for the measurement of radio disturbance voltages, currents and fields in the frequency range 9 kHz to 18 GHz. In addition, requirements are specified for specialized equipment for discontinuous disturbance measurements. The requirements include the measurement of broadband and narrowband types of radio disturbance.

The receiver types covered include the following:

- a) the quasi-peak measuring receiver,
- b) the peak measuring receiver,
- c) the average measuring receiver,
- d) the r.m.s. measuring receiver.

In addition there are specifications for spectrum analyzers, scanning receivers and audio-frequency voltmeters. Specifications for ancillary apparatus are included for: artificial mains networks, current and voltage probes, absorbing clamp, antenna and test site, coupling units for current injection on cables, TEM cells, and reverberating chamber.

The requirements of this publication shall be complied with at all frequencies and for all levels of radio disturbance voltages, currents, power or field strengths within the CISPR indicating range of the measuring equipment.

Methods of measurement are covered in Part 2, and further information on radio disturbance is given in Part 3 of CISPR 16.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 14-1:2000, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

CISPR 16-2:1996, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2: Methods of measurement of immunity and disturbance*

CISPR 16-3: *Specification for radio disturbance and Immunity measuring apparatus and methods – Part 3: Reports and recommendations of CISPR*

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 60315-3:1989, *Methods of measurement on radio receivers for various classes of emissions – Part 3: Receivers for amplitude-modulated sound-broadcasting emissions*

IEC 60315-4:1982, *Methods of measurement on radio receivers for various classes of emissions – Part 4: Radio-frequency measurements on receivers for frequency modulated sound-broadcasting emissions*

CCIR 468-4:1990, *Measurement of audio-frequency noise voltage level in sound broadcasting*

CCITT Recommendation P. 53 of *Blue Book* (1989), Volume V – *Psophometers (apparatus for the objective measurement of circuit noise)*

International Vocabulary of Basic and General Terms in Metrology, International Organization for Standardization, Geneva, 2nd edition, 1993

3 Definitions

For the purpose of this part of CISPR 16, the following definitions apply. Also see IEC 60050(161).

3.1

bandwidth (B_n)

the width of the overall selectivity curve of the receiver between two points at a stated attenuation, below the midband response. The bandwidth is represented by the symbol B_n , where n is the stated attenuation in decibels.

3.2

impulse bandwidth (B_{imp})

$$B_{\text{imp}} = A(t)_{\text{max}} / (2 G_o \times IS)$$

where

$A(t)_{\text{max}}$ is the peak of the envelope at the IF output of the receiver with an impulse area IS applied at the receiver input;

G_o is the gain of the circuit at the centre frequency.

Specifically for two critically-coupled tuned transformers,

$$B_{\text{imp}} = 1,05 \times B_6 = 1,31 \times B_3$$

where

B_6 and B_3 are respectively the bandwidths at the –6 dB and –3 dB points (see clause A.2 in annex A for further information).

3.3

impulse area (IS)

the impulse area (sometimes called impulse strength, IS) is the voltage-time area of a pulse defined by the integral:

$$IS = \int_{-\infty}^{+\infty} V(t) dt \quad (\text{expressed in } \mu\text{Vs or dB}(\mu\text{Vs}))$$

NOTE Spectral density (D) is related to impulse area and expressed in $\mu\text{V/MHz}$ or $\text{dB}(\mu\text{V/MHz})$. For rectangular impulses of pulse duration T at frequencies $f \ll 1/T$, the relationship $D (\mu\text{V/MHz}) = 2 \times 10^6 IS (\mu\text{Vs})$ applies.

3.4

electrical charge time constant (T_C)

the time needed after the instantaneous application of a constant sine-wave voltage to the stage immediately preceding the input of the detector for the output voltage of the detector to reach 63 % of its final value

NOTE This time constant is determined as follows: A sine-wave signal of constant amplitude and having a frequency equal to the mid-band frequency of the i.f. amplifier is applied to the input of the stage immediately preceding the detector. The indication, D , of an instrument having no inertia (e.g., a cathode-ray oscilloscope) connected to a terminal in the d.c. amplifier circuit so as not to affect the behaviour of the detector, is noted. The level of the signal is chosen such that the response of the stages concerned remains within the linear operating range. A sine-wave signal of this level, applied for a limited time only and having a wave train of rectangular envelope is gated such that the deflection registered is $0,63D$. The duration of this signal is equal to the charge time of the detector.

3.5

electrical discharge time constant (T_D)

the time needed after the instantaneous removal of a constant sine-wave voltage applied to the stage immediately preceding the input of the detector for the output of the detector to fall to 37 % of its initial value

NOTE The method of measurement is analogous to that for the charge time constant, but instead of a signal being applied for a limited time, the signal is interrupted for a definite time. The time taken for the deflection to fall to $0,37D$ is the discharge time constant of the detector.

3.6

mechanical time constant (T_M) of a critically damped indicating instrument

$$T_M = T_L / 2\pi$$

where

T_L is the period of free oscillation of the instrument with all damping removed.

NOTE 1 For a critically damped instrument, the equation of motion of the system may be written as:

$$T_M^2 (d^2\alpha / dt^2) + 2T_M (d\alpha / dt) + \alpha = ki$$

where

α is the deflection;

i is the current through the instrument;

k is a constant.

It can be deduced from this relation that this time constant is also equal to the duration of a rectangular pulse (of constant amplitude) that produces a deflection equal to 35 % of the steady deflection produced by a continuous current having the same amplitude as that of the rectangular pulse.

NOTE 2 The methods of measurement and adjustment are deduced from one of the following:

- The period of free oscillation having been adjusted to $2\pi T_M$, damping is added so that $\alpha T = 0,35\alpha_{\max}$.
- When the period of oscillation cannot be measured, the damping is adjusted to be just below critical such that the overshoot is not greater than 5 % and the moment of inertia of the movement is such that $\alpha T = 0,35\alpha_{\max}$.

3.7

overload factor

the ratio of the level that corresponds to the range of practical linear function of a circuit (or a group of circuits) to the level that corresponds to full-scale deflection of the indicating instrument

The maximum level at which the steady-state response of a circuit (or group of circuits) does not depart by more than 1 dB from ideal linearity defines the range of practical linear function of the circuit (or group of circuits).

3.8

symmetric voltage

in a two-wire circuit, such as a single-phase mains supply, the symmetric voltage is the radio-frequency disturbance voltage appearing between the two wires. This is sometimes called the differential mode voltage. If V_a is the vector voltage between one of the mains terminals and earth and V_b is the vector voltage between the other mains terminal and earth, the symmetric voltage is the vector difference ($V_a - V_b$)

3.9

asymmetric voltage

the asymmetric voltage is the radio-frequency disturbance voltage appearing between the electrical mid-point of the mains terminals and earth. It is sometimes called the common mode voltage and is half the vector sum of V_a and V_b , i.e., $(V_a + V_b)/2$

3.10

unsymmetric voltage

the amplitude of the vector voltage, V_a or V_b defined in 3.8 and 3.9. This is the voltage measured by the use of an artificial mains V-network

3.11

CISPR indicating range

it is the range specified by the manufacturer which gives the maximum and the minimum meter indications within which the receiver meets the requirements of this part of CISPR 16

3.12

calibration test site (CALTS)

open area test site with metallic ground plane and tightly specified site attenuation performance in horizontal and vertical electric field polarization.

A CALTS is used for determining the free-space antenna factor of an antenna.

Site attenuation measurements of a CALTS are used for comparison to corresponding site attenuation measurements of a compliance test site, in order to evaluate the performance of the compliance test site

3.13

compliance test site (COMTS)

environment which assures valid, repeatable measurement results of disturbance field strength from equipment under test for comparison to a compliance limit

3.14

antenna

that part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves in a specified way

NOTE 1 In the context of this standard, the balun is a part of the antenna.

NOTE 2 See also the term "wire antenna".

3.15

balun

passive electrical network for the transformation from a balanced to an unbalanced transmission line or device or vice versa

3.16**free-space-resonant dipole**

wire antenna consisting of two straight colinear conductors of equal length, placed end to end, separated by a small gap, with each conductor approximately a quarter-wavelength long such that at the specified frequency the input impedance of the wire antenna measured across the gap is pure real when the dipole is located in the free space

NOTE 1 In the context of this standard, this wire antenna connected to the balun is also called the "test antenna".

NOTE 2 This wire antenna is also referred to as "tuned dipole".

3.17**site attenuation**

site attenuation between two specified positions on a test site is the insertion loss determined by a two-port measurement, when a direct electrical connection between the generator output and receiver input is replaced by transmitting and receiving antennae placed at the specified positions

3.18**test antenna**

combination of the free-space-resonant dipole and the specified balun

NOTE For the purpose of this standard only.

3.19**wire antenna**

a specified structure consisting of one or more metallic wires or rods for radiating or receiving electromagnetic waves

NOTE A wire antenna does not contain a balun.

3.20**asymmetric artificial network (AAN)**

network used to measure (or inject) asymmetric (common mode) voltages on unshielded symmetric signal (e.g. telecommunication) lines while rejecting the symmetric (differential mode) signal

NOTE The term "Y-network" is a synonym for AAN.

3.21**impedance stabilization network (ISN)**

generally an artificial network that provides a stabilized impedance to the EUT; often (e.g. in CISPR 22) used as a synonym for AAN

3.22**coupling/decoupling network (CDN)**

artificial network for the measurement or injection of signals on one circuit while preventing signals from being measured or injected on another circuit

3.23**longitudinal conversion loss (LCL)**

in a one- or two-port network, a measure (a ratio expressed in dB) of the degree of unwanted transverse (symmetric mode) signal produced at the terminals of the network due to the presence of a longitudinal (asymmetric mode) signal on the connecting leads (definition from ITU-T Recommendation O.9¹⁾).

1) ITU-T Recommendation O.9, *Measuring arrangements to assess the degree of unbalance about earth*.

4 Measuring apparatus

4.1 Quasi-peak measuring receivers for the frequency range 9 kHz to 1 000 MHz

The receiver specification depends on the frequency of operation. There is one receiver specification covering the frequency range 9 kHz to 150 kHz (band A), one covering 150 kHz to 30 MHz (band B), one covering 30 MHz to 300 MHz (band C), and one covering 300 MHz to 1 000 MHz (band D).

4.1.1 Input impedance

The input circuit of measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the input impedance shall be nominally 50 Ω with a v.s.w.r. not to exceed 2,0 to 1 when the RF attenuation is 0 and 1,2 to 1 when the RF attenuation is 10 dB or greater.

Symmetric input impedance in the frequency range 9 kHz to 30 MHz: to permit symmetrical measurements a balanced input transformer is used. The preferred input impedance for the frequency range 9 kHz to 150 kHz is 600 Ω . This symmetric input impedance may be incorporated either in the relevant symmetrical artificial network necessary to couple to the receiver or optionally in the measuring receiver.

4.1.2 Fundamental characteristics

The responses to pulses as specified in 4.1.4 are calculated on the basis of the measuring receivers having the following fundamental characteristics.

Table 1 – Fundamental characteristics of quasi-peak receivers

Characteristics	Frequency band		
	Band A 9 kHz to 150 kHz	Band B 0,15 MHz to 30 MHz	Bands C and D 30 MHz to 1 000 MHz
Bandwidth at the –6 dB points, B_6 in kHz	0,22	9	120
Detector electrical charge time constant, in ms	45	1	1
Detector electrical discharge time constant, in ms	500	160	550
Mechanical time constant of critically damped indicating instrument, in ms	160	160	100
Overload factor of circuits preceding the detector, in dB	24	30	43,5
Overload factor of the d.c. amplifier between detector and indicating instrument, in dB	6	12	6
NOTE 1 The definition of mechanical time constant (see 3.6) assumes that the indicating instrument is linear, i.e., equal increments of current produce equal increments of deflection. An indicating instrument having a different relation between current and deflection may be used provided that the instrument satisfies the requirements of this subclause. In an electronic instrument, the mechanical time-constant may be simulated by a circuit. NOTE 2 No tolerance is given for the electrical and mechanical time constants. The actual values used in a specific receiver will be determined by the design to meet the requirements in 4.1.4			

4.1.3 Sine-wave voltage accuracy

The accuracy of measurement of sine-wave voltages shall be better than ± 2 dB when supplied with a sine-wave signal at 50 Ω resistance source impedance.

4.1.4 Response to pulses

NOTE Annexes B and C describe methods for determining the output characteristics of a pulse generator for use in testing the requirements of this subclause.

4.1.4.1 Amplitude relationship (absolute calibration)

The response of the measuring receiver to pulses of impulse area of a) μVs (microvolt second) e.m.f. at 50 Ω source impedance, having a uniform spectrum up to at least b) MHz, repeated at a frequency of c) Hz shall, for all frequencies of tuning, be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of r.m.s. value 2 mV (66 dB(μV)). The source impedances of the pulse generator and the signal generator shall both be the same. A tolerance of $\pm 1,5$ dB shall be permitted on the sine-wave voltage level.

NOTE A lower impulse area may be used together with a proportionally lower amplitude for the unmodulated sinewave input, provided sufficient signal-to-noise ratio is maintained.

Table 2 – Test pulse characteristics for quasi-peak measuring receivers

Frequency range	a) μVs	b) MHz	c) Hz
9 kHz to 150 kHz	13,5	0,15	25
0,15 MHz to 30 MHz	0,316	30	100
30 MHz to 300 MHz	0,044	300	100
300 MHz to 1 000 MHz	0,044	1 000	100

4.1.4.2 Variation with repetition frequency (relative calibration)

The response of the measuring receiver to repeated pulses shall be such that for a constant indication on the measuring receiver, the relationship between amplitude and repetition frequency is in accordance with figures 1a, 1b or 1c.

The response curve for a particular measuring receiver shall lie between the limits defined in the appropriate figure and quantified in table 3.

Table 3 – Pulse response of quasi-peak receivers

Repetition frequency Hz	Relative equivalent level in dB of pulse for stated band			
	Band A 9 kHz to 150 kHz	Band B 0,15 MHz to 30 MHz	Band C 30 MHz to 300 MHz	Band D 300 MHz to 1 000 MHz
1 000	Note 4	$-4,5 \pm 1,0$	$-8,0 \pm 1,0$	$-8,0 \pm 1,0$
100	$-4,0 \pm 1,0$	0 (ref.)	0 (ref.)	0 (ref.)
60	$-0,3 \pm 1,0$	—	—	—
25	0 (ref.)	—	—	—
20	—	$+6,5 \pm 1,0$	$+9,0 \pm 1,0$	$+9,0 \pm 1,0$
10	$+4,0 \pm 1,0$	$+10,0 \pm 1,5$	$+14,0 \pm 1,5$	$+14,0 \pm 1,5$
5	$+7,5 \pm 1,0$	—	—	—
2	$+13,0 \pm 2,0$	$+20,5 \pm 2,0$	$+26,0 \pm 2,0$	$+26,0 \pm 2,0^*$
1	$+17,0 \pm 2,0$	$+22,5 \pm 2,0$	$+28,5 \pm 2,0$	$+28,5 \pm 2,0^*$
Isolated pulse	$+19,0 \pm 2,0$	$+23,5 \pm 2,0$	$+31,5 \pm 2,0$	$+31,5 \pm 2,0^*$

NOTE 1 The influence of the receiver characteristics upon its pulse response is considered in annex D.

NOTE 2 The relationships between the pulse responses of a quasi-peak receiver and receivers with other detector types are given in 4.2.4, 4.3.4.1 and 4.4.4.1.

NOTE 3 The theoretical pulse response curves of quasi-peak and average detector receivers combined on an absolute scale are shown in figure 1d. The ordinate of figure 1d shows the open-circuit impulse areas in dB(μ Vs) corresponding to the open-circuit sine-wave voltage of 66 dB(μ V) r.m.s. The indication on a measuring receiver with an input matched to the calibrating generators will then be 60 dB(μ V). Where the measuring bandwidth is less than the pulse repetition frequency, the curves of figure 1d are valid when the receiver is tuned to a discrete line of the spectrum.

NOTE 4 It is not possible to specify a response above 100 Hz in the frequency range 9 kHz to 150 kHz because of the overlapping of pulses in the i.f. amplifier.

NOTE 5 Annex A deals with the determination of the curve of response to repeated pulses.

NOTE 6 The pulse response is restricted due to overload at the input to the receiver at frequencies above 300 MHz. The values marked with an asterisk (*) in the table are optional and are not essential.

4.1.5 Selectivity

4.1.5.1 Overall selectivity (passband)

The curve representing the overall selectivity of the measuring receiver shall lie within the limits shown in figures 2a, 2b or 2c.

Selectivity shall be described by the variation with frequency of the amplitude of the input sine-wave voltage that produces a constant indication on the measuring receiver.

NOTE For the measurement of equipment that requires higher selectivity at the transition between 130 kHz and 150 kHz (e.g. mains signalling equipment as defined in EN 50065-1/A2), a highpass filter may be added in front of the measuring receiver to achieve the following combined selectivity of CISPR measuring receiver and highpass filter:

Frequency kHz	Relative attenuation dB
150	≤ 1
146	≤ 6
145	≥ 6
140	≥ 34
130	≥ 81

The measuring receiver in conjunction with the highpass filter should fulfil the requirements of this standard.

4.1.5.2 Intermediate frequency rejection ratio

The ratio of the input sine-wave voltage at the intermediate frequency to that at the tuned frequency that produces the same indication of the measuring receiver shall be not less than 40 dB. Where more than one intermediate frequency is used, this requirement shall be met at each intermediate frequency.

4.1.5.3 Image frequency rejection ratio

The ratio of the input sine-wave voltage at the image frequency to that at the tuned frequency that produces the same indication on the measuring receiver shall be not less than 40 dB. Where more than one intermediate frequency is used, this requirement shall be met at the image frequencies corresponding to each intermediate frequency.

4.1.5.4 Other spurious responses

The ratio of the input sine-wave voltage at frequencies other than those specified in 4.1.5.2 and 4.1.5.3 to that at the tuned frequency that produces the same indication on the measuring receiver shall be not less than 40 dB. Examples of the frequencies from which such spurious responses may occur are as follows:

$$(1/m) (nf_L \pm f_i) \text{ and } (1/k) (f_o)$$

where

m, n, k are integers;

f_L is the local oscillator frequency;

f_i is the intermediate frequency;

f_o is the tuned frequency.

NOTE Where more than one intermediate frequency is used, the frequencies f_L and f_i may refer to each of the local oscillator and intermediate frequencies used. In addition, spurious responses may occur when no input signal is applied to the measuring receiver; for example, when harmonics of the local oscillators differ in frequency by one of the intermediate frequencies. The requirements under this heading therefore cannot apply in these latter cases. The effect of these spurious responses is dealt with in 4.1.7.2.

4.1.6 Limitation of intermodulation effects

The response of the measuring receiver shall not be influenced by intermodulation effects when tested as follows.

Arrange the apparatus as shown in figure 3. The pulse generator has a spectrum substantially uniform up to frequency 3) but at least 10 dB down at frequency 4) of the frequencies given in table 4. The band-stop filter has an attenuation at the test frequency of at least 40 dB. Its bandwidth, B_6 , relative to the maximum attenuation of the filter shall lie between the frequencies 1) and 2) given in table 4.

Table 4 – Bandwidth characteristics for inter-modulation test of quasi-peak measuring receivers

Frequency range	1) kHz	2) kHz	3) MHz	4) MHz
9 kHz to 150 kHz (band A)	0,4	4	0,15	0,3
0,15 MHz to 30 MHz (band B)	20	200	30	60
30 MHz to 300 MHz (band C)	500	2 000	300	600
300 MHz to 1 000 MHz (band D)	500	6 000	1 000	2 000

Connect the sine-wave generator output direct to the measuring receiver input and adjust for a convenient reading. Substitute the pulse generator for the sine-wave generator and adjust for the same reading. The pulse repetition frequency shall be 100 Hz for band A and 1 000 Hz for the other bands.

With the pulse generator connected as described above, switching the filter into circuit shall introduce attenuation of not less than 36 dB.

4.1.7 Limitation of receiver noise and internally generated spurious signals

4.1.7.1 Random noise

The background noise shall not introduce an error in excess of 1 dB.

NOTE For a measuring apparatus incorporating attenuation in the intermediate frequency amplifier, this condition will be regarded as being satisfied if the apparatus complies with the following test:

A sine-wave signal is applied to the input of the measuring apparatus and adjusted to a value S_1 , such that the output meter shows a reference deflection θ . An attenuation of 10 dB is introduced in the intermediate-frequency stages. The level of the input signal is increased to S_2 so as to restore the output meter to the deflection θ . The increase of the level of the input signal ($S_2 - S_1$) shall be between 10 dB and 11 dB.

4.1.7.2 Continuous wave

Where more than one intermediate frequency is used, the existence of spurious responses as described in the note to 4.1.5.4 shall not introduce a measurement error in excess of 1 dB for any signal input to the measuring receiver. For a measuring receiver incorporating attenuation in the i.f. amplifier, this requirement shall be regarded as satisfied if the receiver complies with 4.1.7.1 when tested as described in 4.1.7.1, except that the attenuation in the intermediate stages shall be introduced after the last mixer stage.

4.1.8 Screening effectiveness

Screening effectiveness is a measure of the ability of the measuring receiver to operate in an electromagnetic field without degradation. The requirement applies to receivers operating within the "CISPR indication range" specified by the manufacturer as described in 3.11.

The screening of the receiver shall be such that when it is immersed in an ambient electromagnetic field of 3 V/m (unmodulated) at any frequency in the range 9 kHz to 1 000 MHz, an error of not greater than 1 dB is produced at the maximum and minimum of the CISPR indicating range as specified by the manufacturer of the receiver. In cases where a measuring receiver is not immune to the requirement of 3 V/m, the field strength and frequency at which the error exceeds 1 dB shall be stated by the manufacturer. The test shall be performed as described below.

The receiver is placed inside a screened enclosure. An input signal is applied to the receiver via a 2 m long well-screened cable (e.g. semi-rigid), through a feedthrough in the enclosure wall, to a signal generator placed outside the enclosure. The level of the input signal shall be at the maximum and the minimum of the CISPR indication range as specified by the manufacturer of the receiver. All other coaxial terminals of the receiver shall be terminated in their characteristic impedance.

Only essential leads (e.g. mains and input cables) for the normal use of the measuring receiver in its minimum configuration (excluding options such as headphones) shall be connected during the test. The leads shall have the lengths and be arranged as in typical use.

The strength of the ambient field in the vicinity of the measuring receiver shall be measured by a field strength monitor.

The receiver meter indication in the presence of the ambient electromagnetic field shall differ by not more than 1 dB from the meter indication when the field is absent.

4.1.8.1 Limitation of radio-frequency emissions from the measuring receiver

4.1.8.1.1 Conducted emissions

The radio disturbance voltage at any connecting pin of external lines (not only the mains terminals) shall not exceed the limits for class B equipment given in 5.1 of CISPR 11*. The measurement of the radio disturbance voltage is however not required on the inner conductors of screened connections to screened equipment. The local oscillator injection power at the measuring receiver input terminated with its characteristic impedance shall not exceed 34 dB(pW) which is equivalent to 50 μ V across 50 Ω .

4.1.8.1.2 Radiated emissions

The radio disturbance field strength emitted by the measuring receiver shall not exceed the limits for class B equipment given in 5.2 of CISPR 11*, for the frequency range of 9 kHz to 1 000 MHz. The limits shall also apply for frequency bands (ISM frequencies) listed in table 1 of the same publication. In the frequency range of 1 GHz to 18 GHz, a limit of 45 dB(pW) shall apply.

* CISPR 11:1990, *Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and media (ISM) radio-frequency equipment.*

Before performing radiated and conducted emission measurements, it is essential that the noise contributions of the test equipment do not affect the measured results (e.g. computer control).

4.1.9 Facilities for connection to a discontinuous disturbance analyzer

For all bands the disturbance measuring receiver shall have both an intermediate-frequency output and an output from the quasi-peak detector for the measurement of discontinuous disturbance. The loading of these outputs shall have no influence on the indicating instrument.

4.2 Peak measuring receivers for the frequency range 9 kHz to 1 000 MHz

This clause specifies requirements for measuring receivers employing a peak detector when used for the measurement of impulsive disturbance.

4.2.1 Input impedance

The input circuit of measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the input impedance shall be nominally 50 Ω with a VSWR not to exceed 2,0 to 1 when the RF attenuation is 0 and 1,2 to 1 when the RF attenuation is 10 dB or greater.

Symmetric input impedance in the frequency range 9 kHz to 30 MHz: To permit symmetrical measurements a balanced input transformer is used. The preferred input impedance is 600 Ω for the frequency range 9 kHz to 150 kHz. This symmetric input impedance may be incorporated either in the relevant symmetrical artificial network necessary to couple to the receiver or optionally in the measuring receiver.

4.2.2 Fundamental characteristics

4.2.2.1 Bandwidth

For all types of broadband disturbance except non-overlapping disturbance, the actual value of the bandwidth shall be stated when the disturbance level is quoted and the bandwidth at the 6 dB points shall lie within the values in table 5.

Table 5 – Bandwidth requirements

Frequency range	Bandwidth B_6	Preferred BW
9 kHz to 150 kHz (band A)	100 Hz to 300 Hz	200 Hz
0,15 MHz to 30 MHz (band B)	8 kHz to 10 kHz	9 kHz
30 MHz to 300 MHz (bands C and D)	100 kHz to 500 kHz	120 kHz
NOTE Since the response of a peak measuring receiver to non-overlapping pulses is proportional to its impulse bandwidth, either the actual bandwidth is quoted in the result or the level may be quoted as that "in a 1 MHz bandwidth" calculated by dividing the measured value by the impulse bandwidth in MHz (see 3.2). For other types of broadband disturbance this procedure would introduce an error.		

4.2.2.2 Charge and discharge time constants ratio

In order to achieve a meter reading within 10 % of the true value of the peak at a repetition rate of 1 Hz, the discharge time constant to charge time constant ratio shall be not less than the values given below.

- a) $1,89 \times 10^4$ in the frequency range 9 kHz to 150 kHz;
- b) $1,25 \times 10^6$ in the frequency range 150 kHz to 30 MHz;
- c) $1,67 \times 10^7$ in the frequency range 30 MHz to 1 000 MHz.

If a peak-hold facility is incorporated, the hold time shall be capable of being set to values between 30 ms and 3 s.

NOTE Care should be taken to ensure that any recording instrument used is capable of full response within the selected hold time.

4.2.2.3 Overload factor

For peak measuring receivers, the overload factor need not be so great as for other types of measuring receiver. For most direct-reading detectors, the overload factor need be only a little greater than unity. The overload factor shall be adequate for the time-constants used (see 4.2.2.2).

4.2.3 Sine-wave voltage accuracy

The accuracy of measurement of sine-wave voltages shall be better than ± 2 dB when supplied with a sine-wave signal at a 50 Ω resistive source impedance.

4.2.4 Response to pulses

The response of the measuring receiver to pulses of impulse area $1,4/B_{\text{imp}}$ mVs (where B_{imp} is in hertz) e.m.f. at 50 Ω source impedance shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of r.m.s. value 2 mV (66 dB(μ V)). The source impedances of the pulse generator and the signal generator shall both be the same. The pulses shall have a uniform spectrum according to table 2 of 4.1.4.1.

A tolerance of $\pm 1,5$ dB is permitted in the sine-wave voltage level and this requirement applies for all pulse repetition frequencies for which no overlapping pulses occur at the output of the i.f. amplifier.

NOTE 1 Annexes B and C describe methods for determining the output characteristics of pulse generators for use in testing the requirements of this subclause.

NOTE 2 At a repetition rate of 25 Hz for band A and 100 Hz for the other bands, the relationship between the indications of a peak measuring receiver and a quasi-peak measuring receiver with the preferred bandwidth are given in table 6.

Table 6 – Relative pulse response of peak and quasi-peak measuring receivers for the same bandwidth

Frequency	I_S mVs	B_{imp} Hz	Ratio peak/quasi-peak (dB) for pulse repetition rate	
			25 Hz	100 Hz
Band A	$6,67 \times 10^{-3}$	$0,21 \times 10^3$	6,1	–
Band B	$0,148 \times 10^{-3}$	$9,45 \times 10^3$	–	6,6
Bands C and D	$0,011 \times 10^{-3}$	$126,0 \times 10^3$	–	12,0

4.2.5 Selectivity

Since the bandwidth requirements of 4.2.2.1 allow variations from the bandwidths given in figures 2a, 2b and 2c, these selectivity curves apply to peak measuring receivers as regards shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in figure 2a.

The requirements of 4.1.5.2, 4.1.5.3 and 4.1.5.4 apply.

4.2.6 Inter-modulation effects, receiver noise, and screening

The requirements of 4.1.6, 4.1.7 and 4.1.8 apply.

4.3 Average measuring receivers for the frequency range 9 kHz to 1 000 MHz

This type of receiver has a detector designed to indicate the average value of the envelope of the signal passed through the pre-detector stages. The average detector is used for the measurement of narrowband signals to overcome problems associated with either modulation content or the presence of broadband noise. Average measuring receivers are not generally used for the measurement of impulsive disturbance.

4.3.1 Input impedance

The input circuit of measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the input impedance shall be nominally 50 Ω with a VSWR not to exceed 2,0 to 1 when the RF attenuation is 0 and 1,2 to 1 when the RF attenuation is 10 dB or greater.

Symmetric input impedance in the frequency range 9 kHz to 150 kHz: To permit symmetrical measurements a balanced input transformer is used. The preferred input impedance for the frequency range 9 kHz to 150 kHz is 600 Ω . This symmetric input impedance may be incorporated either in the relevant symmetrical artificial network necessary to couple to the receiver or optionally in the measuring receiver.

4.3.2 Fundamental characteristics

4.3.2.1 Bandwidth

The bandwidths B_6 shall lie within the values in table 7:

Table 7 – Bandwidth requirements

Frequency range	Bandwidth B_6	Preferred BW
9 kHz to 150 kHz (band A)	100 Hz to 300 Hz	200 Hz
150 kHz to 30 MHz (band B)	8 kHz to 10 kHz	9 kHz
30 MHz to 1 000 MHz (bands C and D)	100 kHz to 500 kHz	120 kHz
NOTE The subject of bandwidth is discussed in annex E, clause E.1. If a bandwidth other than the preferred one is used, it shall be stated when the disturbance level is quoted.		

4.3.2.2 Overload factor

The overload factor for circuits preceding the detector at a pulse repetition rate of n Hz shall be B_{imp}/n , with B_{imp} in Hz.

The receiver shall not overload for pulse rates equal to or greater than 25 Hz for band A, 500 Hz for band B, and 5 000 Hz for bands C and D.

NOTE With this type of receiver it will not, in general, be possible to provide a sufficient overload factor to prevent non-linear operation of the receiver at very low pulse rates (the response to a single pulse is not defined).

4.3.3 Sine-wave voltage accuracy

The accuracy of measurement of sine-wave voltages shall be better than ± 2 dB when supplied with a sine-wave signal at 50 Ω resistive source impedance.

4.3.4 Response to pulses

NOTE Annexes B and C describe methods for determining the output characteristics of pulse generators for use in testing the requirements of this clause.

4.3.4.1 Amplitude relationship

The response of the measuring receiver to pulses of repetition rate n Hz and impulse area e.m.f. at 50 Ω source impedance equal to $1,4/n$ mVs, shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of r.m.s. value 2 mV (66 dB(μ V)). The source impedances of the pulse generator and the signal generator shall both be the same. The pulses shall have a uniform spectrum according to table 2 of 4.1.4.1. The value of n shall be 25 for band A, 500 for band B, and 5 000 for bands C and D. A tolerance of 2,5 dB/–0,5 dB is permitted on the sine-wave voltage level.

NOTE 1 A lower impulse area may be used together with a proportionally lower amplitude for the unmodulated sine-wave input, provided sufficient signal-to-noise ratio is maintained.

NOTE 2 At repetition frequencies of 25, 100, 1 000 and 10 000 Hz, the relationship between the indications of an average and a quasi-peak measuring receiver of the same bandwidth, assuming adequate overload factors and a constant output level, is given in table 8.

Table 8 – Relative pulse response of average and quasi-peak measuring receivers for the same bandwidth

Frequency range of measuring receiver	Ratio quasi-peak/average indications (dB) for pulse repetition rate				
	25 Hz	100 Hz	500 Hz	1 000 Hz	5 000 Hz
9 kHz to 150 kHz (band A)	12,4				
0,15 MHz to 30 MHz (band B)		(32,9)	22,9	(17,4)	
30 MHz to 1 000 MHz (bands C/D)				(38,1)	26,3
NOTE Values in brackets are for information only.					

4.3.4.2 Variation with repetition frequency

The response of the measuring receiver to repeated pulses shall be such that, for a constant indication on the measuring receiver, the relationship between amplitude and repetition frequency is in accordance with the following law.

Amplitude proportional to (repetition frequency)⁻¹

A tolerance of +3 dB to -1 dB is permitted in the frequency range from the lowest repetition frequency usable as determined from overload considerations to a frequency equal to $B_3/2$.

NOTE The theoretical pulse response curves of quasi-peak and average detector receivers, combined on an absolute scale, are shown in figure 1d.

4.3.4.3 Response to intermittent, unsteady and drifting narrowband disturbances

The response to intermittent, unsteady and drifting narrowband disturbances shall be such that the measurement result is equivalent to the peak reading of a meter with a time constant of 160 ms for bands A and B and of 100 ms for bands C and D, as depicted in Figure 61. The time constant is as defined in A.3.1. This can be accomplished by a meter simulating network following the envelope detector of the receiver. The peak reading may be taken, for example, by continuous monitoring of the meter output using an A/D converter and a microprocessor, as shown in Figure 60.

It is deduced from the above requirement that an average measuring receiver shall yield the maximum reading listed in table 21 for a radiofrequency sine-wave input signal modulated with repeated rectangular pulses having the duration and period indicated in the table. A tolerance of $\pm 1,0$ dB is allowed for this requirement.

Table 21 – Maximum reading of average measuring receivers for a pulse-modulated sine-wave input in comparison with the response to a continuous sine-wave having the same amplitude

Repeated rectangular pulses for modulation	Band A/B receiver $T_M = 0,16$ s	Band C/D receiver $T_M = 0,1$ s
Duration = T_M Period = 1,6 s	0,353 (= -9,0 dB)	0,353 (= -9,0 dB)

4.3.5 Selectivity

For receivers with a bandwidth of 200 Hz (for frequency range 9 kHz to 150 kHz) or a bandwidth of 9 kHz (for frequency range 0,15 MHz to 30 MHz) the overall selectivity shall be within the limits shown in figures 2a and 2b, respectively. For receivers with a bandwidth of 120 kHz (for frequency range 30 MHz to 1 000 MHz), the overall selectivity shall be within the limits shown in figure 2c. For receivers having other bandwidths, the figures 2a, 2b and 2c describe the shape only, and the frequency axis shall be scaled accordingly.

The requirements of 4.1.5.2, 4.1.5.3 and 4.1.5.4 apply.

NOTE For the measurement of equipment that requires higher selectivity at the transition between 130 kHz and 150 kHz (e.g. mains signalling equipment as defined in EN 50065-1/A2), a highpass filter may be added in front of the measuring receiver to achieve the following combined selectivity of CISPR measuring receiver and highpass filter:

Frequency kHz	Relative attenuation dB
150	≤ 1
146	≤ 6
145	≥ 6
140	≥ 34
130	≥ 81

The measuring receiver in conjunction with the highpass filter should fulfil the requirements of this standard.

4.3.6 Inter-modulation effects, receiver noise, and screening

The requirements of 4.1.6, 4.1.7 and 4.1.8 apply.

4.4 RMS measuring receivers for the frequency range 9 kHz to 1 000 MHz

4.4.1 Input impedance

The input circuit of measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the input impedance shall be nominally 50 Ω with a VSWR not to exceed 2,0 to 1 when the RF attenuation is nil and 1,2 to 1 when the RF attenuator is 10 dB or greater.

Symmetric input impedance in the frequency range 9 kHz to 30 MHz: To permit symmetrical measurements a balanced input transformer is used. The preferred input impedance for the frequency range 9 kHz to 150 kHz is 600 Ω . This symmetric input impedance may be incorporated either in the relevant symmetrical artificial network necessary to couple to the receiver or optionally in the measuring receiver.

4.4.2 Fundamental characteristics

4.4.2.1 Bandwidth

Since the response of an r.m.s. meter is proportional to the square root of the bandwidth for any type of broadband disturbance, the actual bandwidth need not be specified. For such broadband disturbance, the measurement result may be quoted as that "in 1 kHz bandwidth", by dividing the measured value by the square root of the power bandwidth given in kilohertz. The actual value of the bandwidth shall be stated when the disturbance level is quoted.

4.4.2.2 Overload factor

The overload factor for circuits preceding the detector at a pulse repetition rate of n Hz shall be $1,27(B_3/n)^{1/2}$, with B_3 in Hz.

NOTE 1 With this type of detector it will not, in general, be possible to provide a sufficient overload factor to prevent non-linear operation of the instrument at very low pulse repetition rates (the response to a single pulse is not defined). In any application of this detector, the minimum pulse repetition rate without overload shall be determined.

NOTE 2 Annex A describes the calculation for the overload factor.

4.4.3 Sine-wave voltage accuracy

The accuracy of measurement of sine-wave voltages shall be better than ± 2 dB when supplied with a sine-wave signal at 50 Ω resistive source impedance.

4.4.4 Response to pulses

NOTE Annexes B and C describe methods for determining the output characteristics of pulse generators for use in testing the requirements of this clause.

4.4.4.1 Amplitude relationship

The response of the measuring receiver for band A to pulses of impulse area $[278 (B_3)^{-1/2}]$ μ Vs e.m.f. at 50 Ω source impedance having a uniform spectrum up to at least the highest tuneable frequency of the receiver, repeated at a frequency of 25 Hz shall, for all frequencies of tuning, be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of 2 mV (66 dB(μ V)) r.m.s. For the measuring receivers for bands B, C and D, the corresponding values are $[139 (B_3^{-1/2})]$ μ Vs and 100 Hz. The source impedances of the pulse generator and the signal generator shall both be the same. A tolerance of $\pm 1,5$ dB is permitted in the sine-wave voltage levels prescribed above.

NOTE 1 Annex A describes the calculation for the pulse response of the r.m.s. detector. At a repetition frequency of 25 Hz and 100 Hz, respectively, the relationship between the indications of an r.m.s. and a quasi-peak measuring receiver of the same bandwidth is given in table 9.

NOTE 2 A lower impulse area may be used together with a proportionally lower amplitude for the unmodulated sine-wave input, provided sufficient signal-to-noise ratio is maintained.

Table 9 – Relative pulse response of r.m.s. and quasi-peak measuring receivers

Frequency range of measuring receiver	Pulse repetition range Hz	Ratio quasi-peak/r.m.s. indications dB
9 kHz to 150 kHz (band A)	25	4,2
0,15 MHz to 30 MHz (band B)	100	14,3
30 MHz to 1 000 MHz (bands C and D)	100	20,1

4.4.4.2 Variation with repetition frequency

The response of the measuring receiver to repeated pulses shall be such that, for a constant indication on the measuring receiver, the relationship between amplitude and repetition frequency shall be in accordance with the following law:

Amplitude proportional to (repetition frequency)^{-1/2}

The response curve for a particular receiver shall lie between the limits in table 10.

Table 10 – Pulse response of r.m.s. receiver

Repetition frequency Hz	Relative equivalent level of pulse in dB	
	Band A	Bands B, C and D
1 000	–	–10 ± 1,0
100	–6 ± 0,6	0 (ref.)
25	0 (ref.)	+6 ± 0,6
20	+1 ± 0,7	+7 ± 0,7
10	+4 ± 1,0	+10 ± 1,0
2	+11 ± 1,7	+17 ± 1,7
1	+14 ± 2,0	+20 ± 2,0

4.4.5 Selectivity

Since the bandwidth requirements of 4.4.2.1 allow variations from the bandwidths given in figures 2a, 2b and 2c, these selectivity curves apply to r.m.s. measuring receivers as regards shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in figure 2a.

The requirements of 4.1.5.2, 4.1.5.3 and 4.1.5.4 apply.

4.4.6 Inter-modulation effects, receiver noise, and screening

The requirements of 4.1.6, 4.1.7 and 4.1.8 apply.

4.5 Spectrum analyzers and scanning receivers

4.5.1 Spectrum analyzers and scanning receivers for the frequency range 9 kHz to 1 000 MHz

Spectrum analyzers and scanning receivers intended for the measurement of disturbance in the frequency range 9 kHz to 1 000 MHz shall comply with the performance requirements specified in 4.1, 4.2 or 4.3.

4.5.2 Spectrum analyzers and scanning receivers for the frequency range 1 GHz to 18 GHz

The spectrum analyzer is the most commonly used equipment for measurements above 1 GHz. The measurement method in this range is based on this equipment. The use of measuring receivers with stepped frequency scanning is however not excluded. The indications below apply, as appropriate.

Requirements for measuring apparatus in the frequency range 1 GHz to 18 GHz are listed below:

a) **Resolution bandwidth (RBW)**

For general measurements above 1 GHz, the resolution bandwidth (RBW) of the measuring receiver shall be 1 MHz. In justified cases, depending on the system to be protected, the source and the emission limit, narrower or wider RBW may be specified by the relevant product committee.

The chosen value shall be defined with a tolerance of $\pm 10\%$ (1 MHz $\pm 10\%$ for example). This RBW shall be defined as the impulse bandwidth of the measuring apparatus.

b) **Detector**

The peak detector is a standard detector on spectrum analyzers and is therefore the preferred detector for emission measurements above 1 GHz. A maximum hold function may be used for signals varying with time.

Additional measurements with a weighting detector may also be applicable to some products or product families if it is appropriate to evaluate its interfering potential towards radio systems. A weighting function can be achieved by reducing the video bandwidth of the spectrum analyzer.

NOTE For weighted measurements based on a reduction of the video bandwidth, care should be taken that the scanning time is sufficiently long to allow the video filter to respond in a correct way.

c) **Video bandwidth (VBW)**

For measurements with a peak detector, the VBW shall be higher than the RBW (1 MHz, see 4.5.2 a)). On generally available measuring equipment, this corresponds to a VBW set to three times the RBW.

To reach weighted measurements, the VBW should be set to a value lower than the modulation bandwidth of the signal to be measured. The evaluation of the correct VBW can be done by reducing the VBW until the indicated amplitude changes by less than approximately 1 dB. Linearity reserve requirements for the stages preceding the detector are under consideration.

NOTE For peak measurements, the output signal of the peak detector can be read from the display operating in either the linear or the logarithmic mode. For weighted measurements, if the linear mode is used, the result will correspond to the average level of the measured signal; if the logarithmic mode is used, the result will correspond to the average of the logarithmic values of the measured signal. Thus, for a square signal taking alternatively the values 20 dB(μ V) and 60 dB(μ V), the level obtained in the logarithmic mode is 40 dB(μ V), whereas in the linear mode, the level of 54,1 dB(μ V) represents the true average value of the signal.

d) **Screening effectiveness**

For the frequency range of 1 GHz to 18 GHz, the screening effectiveness is under consideration.

e) **Input filter**

A filter shall be provided at the input of the spectrum analyzer to give sufficient attenuation at the fundamental frequency of certain equipment under test to protect the input circuits of the analyzer from overload and damage and to prevent the generation of harmonic and intermodulation signals when measuring weak spurious signals in the presence of a strong fundamental signal.

NOTE 1 30 dB filter attenuation at the fundamental frequency of the equipment under test is normally adequate.

NOTE 2 A number of such filters may be required to deal with more than one fundamental frequency.

f) **Display**

To permit visual observations while using the slower sweep times, the spectrum analyzer shall be provided with some form of display storage.

g) **Scanning time**

The scan time for the displayed frequency range should be capable of being varied, e.g., from 0,1 s to 10 s.

NOTE The definition of additional parameters of the measuring apparatus such as input impedance, linearity, sine-wave voltage accuracy, absolute calibration, etc. is presently under consideration.

4.6 Audio-frequency voltmeter

In the CISPR, a voltmeter is needed which can be utilized for checking purposes, which when connected to the output of a good radio receiver will give significant measurements compared with a standard CISPR quasi-peak measuring receiver. It should be noted, however, that the use of the meter in this manner as compared to a normal CISPR receiver will be limited in performance by the bandwidth, overload, non-linearity and spurious responses of the radio receiver. The IEC has prepared specifications* for measuring noise at the audio output of receivers.

The voltmeter also enables assessment to be made of the performance of audio systems subjected to continuous and impulsive noise. It contains various circuits which can be selected depending on the function to be served. Where a specific function is desired, only those circuits necessary for that function need be included.

A block diagram of the voltmeter is shown in figure 4.

4.6.1 Fundamental characteristics

4.6.1.1 Input impedance

The rated input impedance shall be one or more of the following values, unbalanced, 50 Ω and a high impedance not less than 6 000 Ω , and balanced, 600 Ω .

The balance of the 600 Ω input shall be such that when a voltage U is applied between the voltmeter ground and the mid-point of a 600 Ω resistor connected across the input terminals, the output indication shall not exceed 0,1 mV. The value of the voltage U for the test shall be in accordance with table 11:

Table 11 – Balance requirement

Frequency	Asymmetrical input voltage for 0,1 mV symmetrical output voltage	Common mode rejection
Hz	U (V)	dB
50	200	126
250	40	112
1 000	10	100

4.6.1.2 Sensitivity

The measuring range of the voltmeter for an input frequency of 1 kHz shall cover 0,3 mV full scale to 1 V full scale.

* IEC 60315-3 for a.m. receivers.
IEC 60315-4 for f.m. receivers.

4.6.1.3 Frequency response

The response of the components of the voltmeter to sine-wave input signals shall be as follows:

- a) frequency response of the wideband amplifier: 3 dB at 16 Hz and 16 kHz
- b) telephone psophometric filter: see figure 5**
- c) sound programme psophometric filter: see figure 6***

4.6.2 Sine-wave voltage accuracy

The accuracy of measurement of sine-wave voltages shall be better than ± 2 dB when supplied with a sine-wave signal at 50 Ω resistive source impedance.

4.6.3 Screening

The screening of the meter shall be such that when it is immersed in an alternating magnetic field of 1 A/m at the mains supply frequency, an error of not greater than 1 dB is produced at any measuring level.

NOTE Specifications of screening effectiveness to ambient electromagnetic fields are under consideration.

4.6.4 Requirements for use as a quasi-peak meter

The sound programme psophometric filter shall be used.

4.6.4.1 Quasi-peak meter fundamental characteristics

The response to pulses as specified in 4.6.4.2 and 4.6.4.3 are calculated on the basis of the following nominal fundamental characteristics.

– Overload factor	30 dB
– Charging time constant	1 ms
– Discharging time constant	160 ms
– Mechanical time constant of the critically damped indicating instrument	160 ms

NOTE When used with a measuring receiver, the time constants shall be adjusted to suit the requirements of 4.6.4.2 and 4.6.4.3.

4.6.4.2 Response to pulses

The response to both positive and negative pulses of impulse strength 0,075 μ Vs having a uniform spectrum up to at least 20 kHz, repeated at a frequency of 100 Hz, shall be equal to the response to a 1 000 Hz sine-wave having an e.m.f. of r.m.s. value of 2 mV (66 dB(μ V)). The source impedances of the pulse generator and the sine-wave generator shall be the same. A tolerance of $\pm 1,5$ dB is permitted on the sine-wave voltage level.

** See CCITT Recommendation P.53, Psophometers (apparatus for the objective measurement of circuit noise). *Blue Book*, Vol. V (1989).

*** See CCIR Recommendation 468-4 (1990).

4.6.4.3 Variation with repetition frequency

The response of the meter to repeated pulses shall be such that for a constant indication on the meter, the relationship between amplitude and repetition frequency shall be in accordance with the limits quoted in table 12:

Table 12 – Pulse response requirement

Repetition frequency Hz	Relative equivalent level of pulse dB
1 000	$-4,5 \pm 1,0$
100	0 (reference)
20	$6,5 \pm 1,0$
5	$14,5 \pm 2,0$
Isolated pulse	$23,5 \pm 3,0$

4.6.5 Requirements for use as an r.m.s. meter

4.6.5.1 RMS meter fundamental characteristic

The time constant of the electrical circuit of the voltmeter shall be not longer than 1 s.

4.6.5.2 Response to pulses

For an r.m.s. audio voltmeter with a 3 dB bandwidth B_3 in Hz including the frequency weighting due to the psophometric filter, if any, the response of the meter to pulses of impulse area $139(B_3)^{-1/2} \mu\text{Vs}$ having a uniform spectrum up to at least 20 kHz, repeated at a frequency of 100 Hz, shall be equal to the response to a sine-wave having an r.m.s. value of 2 mV at the frequency giving the greatest response. The source impedances of the pulse generator and the sine-wave generator shall be the same. A difference of $\pm 1,5$ dB between the two responses is allowed.

4.6.5.3 Variation with repetition frequency

The response of the voltmeter to repeated pulses shall be such that for a constant indication on the meter, the relationship between amplitude of pulses and repetition frequency shall be in accordance with:

$$\text{Amplitude proportional to } (\text{repetition frequency})^{-1/2}$$

A tolerance of $\pm 1/10$ of the relevant equivalent level of pulse in decibels referred to the level at 100 Hz repetition frequency is allowed.

NOTE The lowest repetition frequency at which it is possible to measure accurately is determined by the overall bandwidth of the voltmeter and a possible receiver (or filter) before it and by the overload factor of the meter (assuming the receiver is not being overloaded). For a low-frequency passband of 9 kHz at 6 dB down and 30 dB overload factor (as for the quasi-peak voltmeter) the lowest repetition frequency is 12 Hz.

5 Ancillary apparatus

5.1 Artificial mains networks

An artificial mains network is required to provide a defined impedance at radio frequencies at the terminals of the equipment under test, to isolate the test circuit from unwanted radio-frequency signals on the supply mains, and to couple the disturbance voltage to the measuring receiver.

There are two basic types of artificial mains networks, the V-network which couples the unsymmetric voltages, and the delta-network which couples the symmetric and the asymmetric voltages separately.

For each mains conductor, there are three terminals: the mains terminal for connection to the supply mains, the equipment terminal for connection to the equipment under test, and the disturbance output terminal for connection to the measuring equipment.

NOTE Examples of circuits of artificial mains networks are given in annex F.

5.1.1 Network impedance

The impedance of an artificial mains network is the magnitude of the impedance with respect to reference earth measured at an equipment terminal when the corresponding disturbance output terminal is terminated with $50\ \Omega$.

The impedance at the equipment terminals of the artificial mains network defines the termination impedance presented to the equipment under test. For this reason, when a disturbance output terminal is not connected to the measuring receiver, it shall be terminated by $50\ \Omega$.

The impedance of each of the mains conductors of the network shall comply with 5.1.2, 5.1.3, 5.1.4, 5.1.5 or 5.1.6 as appropriate, for any value of external impedance, including a short circuit or the RF filter described in 5.1.7, connected between the corresponding mains terminal and reference earth. This requirement shall be met at all temperatures which the network may reach under normal conditions for continuous currents up to the specified maximum. The requirement shall also be met for peak currents up to the specified maximum.

5.1.2 $50\ \Omega/50\ \mu\text{H} + 5\ \Omega$ artificial mains V-network (for use in the frequency range 9 kHz to 150 kHz)

The network shall have the impedance versus frequency characteristic shown in figure 7a in the relevant frequency range. A tolerance of $\pm 20\%$ is permitted.

NOTE This network may be constructed such that it can meet the combined impedance requirements of this subclause and 5.1.3.

5.1.3 $50\ \Omega/50\ \mu\text{H}$ artificial mains V-network (for use in the frequency range 0,15 MHz to 30 MHz)

The network shall have the impedance versus frequency characteristic shown in figure 7b in the relevant frequency range. A tolerance of $\pm 20\%$ is permitted.

NOTE The $50\ \Omega/50\ \mu\text{H} + 5\ \Omega$ artificial mains V-network of 5.1.2 may also meet the impedance requirement of this subclause.

5.1.4 $50\ \Omega/5\ \mu\text{H} + 1\ \Omega$ artificial mains V-network (for use in the frequency range 150 kHz to 100 MHz)

The network shall have the impedance versus frequency characteristic shown in figure 8. A tolerance of $\pm 20\%$ is permitted.

5.1.5 150 Ω artificial mains V-network (for use in the frequency range 150 kHz to 30 MHz)

The network shall have an impedance of magnitude $150 \pm 20 \Omega$ with a phase angle not exceeding 20° .

5.1.6 150 Ω artificial mains delta-network (for use in the frequency range 150 kHz to 30 MHz)

The network shall have an impedance of magnitude $150 \pm 20 \Omega$ with a phase angle not exceeding 20° , both between the equipment terminals and between the two equipment terminals joined together and reference earth.

For the measurement of the symmetric voltage, a screened and balanced transformer is required. To avoid appreciable modification of the impedance of the network, the input impedance of the transformer shall be not less than $1\,000 \Omega$ at all frequencies concerned. The voltage measured by the measuring receiver depends on the network component values and the transformer ratio. The network shall be calibrated.

5.1.6.1 Balance of the 150 Ω artificial mains delta-network

The balance of the system comprising the network and the measuring receiver connected thereto via the transformer shall be such that the measurement of symmetric voltage shall be substantially unaffected by the presence of an asymmetric voltage. The balance shall be measured using the circuit shown in figure 9.

A voltage U_a is injected from a generator having an internal impedance of 50Ω , between reference earth and the common point of two resistors each $200 \Omega \pm 1\%$. The other end of these resistors is connected to the equipment terminals of the artificial mains network.

A voltage U_s is measured in the position for symmetric voltage measurement. The ratio U_a/U_s shall be greater than 20:1 (26 dB).

5.1.7 Isolation

To ensure that at any test frequency unwanted signals existing on the supply mains do not affect the measurement, an additional RF low-pass filter may be required, inserted between the artificial mains network and the supply mains. With this filter inserted, the impedance requirements given in 5.1.2, 5.1.3, 5.1.4, 5.1.5, and 5.1.6 shall be met. The components forming this filter shall be enclosed in a metallic screen directly connected to the reference earth of the measuring system.

5.1.8 Current carrying capacity and series voltage drop

The maximum continuous currents and the maximum peak current shall be specified. The voltage applied to the equipment under test when passing continuous currents up to the maximum shall be not less than 95 % of the mains voltage at the mains terminals of the artificial mains network.

5.1.9 Modified reference earth connection

The measurement of some types of equipment may require the insertion of an impedance in the reference earth conductor in the artificial mains networks in 5.1.2 and 5.1.3 following the requirements of the related product publications. This is inserted at point X marked in the reference earth lead in figures 23 and 24, respectively. The impedance to be inserted is either a 1,6 mH inductor or an impedance conforming to the impedance requirement of 5.1.2 or 5.1.3, as appropriate for the frequency range.

NOTE For safety reasons, the 5Ω resistor mentioned in 5.1.2 should be omitted.

5.1.10 Calibration of the voltage division factor of artificial mains V-networks

The voltage division factor between the EUT port of the V-network and the RF output port shall be measured and taken into consideration during the measurement of the disturbance voltage. A procedure to measure the voltage division factor is contained in clause F.8.

5.2 Current and voltage probes

5.2.1 Current probes

The asymmetrical disturbance currents of cables can be measured, without making direct conductive contact with the source conductor and without modification of its circuit, by use of specially developed clamp-on current transformers. The utility of this method is self-evident; complex wiring systems, electronic circuits, etc., may be measured without interruption of the normal operation or configuration. The current probe is constructed so that it may be conveniently clamped around the conductor to be measured. The conductor represents a one-turn primary winding. The secondary winding is contained within the current probe.

Current probes can be constructed for measurements in the frequency range 30 Hz to 1 000 MHz, although the primary measurement range is 30 Hz to 100 MHz. Beyond 100 MHz the standing currents in conventional power systems require that the current probe location be optimized for detection of the maximum current.

Current probes are designed to provide a flat frequency response over a passband. At frequencies below this flat passband accurate measurements can still be made but with decreased sensitivity due to reduced transfer impedances. At frequencies above the flat passband measurements are not accurate due to resonances in the current probe.

With an additional shielding structure, a current probe may be used to measure either the asymmetrical (common mode) or symmetrical (differential mode) current. Clause I.5 of annex I contains some construction details.

5.2.1.1 Construction

The current probe shall be constructed so as to enable the measurement of the current without disconnecting the lead under measurement.

Annex I contains some typical constructions of current probes.

5.2.1.2 Characteristics

Insertion impedance	1 Ω impedance maximum
Transfer impedance*	0,1 to 5 Ω in the flat linear range; 0,001 to 0,1 Ω below the flat linear range (current probe terminated into 50 Ω)
Added shunt capacitance	Less than 25 pF between the current probe housing and measured conductor
Frequency response	Transfer impedance is calibrated over a specified frequency range; the range of individual probes is typically 100 kHz to 100 MHz, 100 MHz to 300 MHz, and 200 MHz to 1 000 MHz
Pulse response	Under consideration

* The reciprocal transfer admittance, (in dB(S)), may be used instead. When expressed in decibels, the admittance is added to the reading of the measuring receiver. For the calibration of the transfer impedance or admittance, it may be necessary to use a jig designed for the purpose. See annex I.

Magnetic saturation	The maximum d.c. or a.c. mains current in the primary lead for a measurement error less than 1 dB shall be specified
Transfer impedance tolerance	Under consideration
Influence of external magnetic fields	40 dB reduction in indication when a current carrying conductor is removed from the current probe opening to a position adjacent to the probe
Influence of electric fields	Not susceptible to fields <10 V/m
Influence of orientation	Less than 1 dB up to 30 MHz and 2,5 dB from 30 MHz to 1 000 MHz, when used on a conductor of any size placed anywhere inside the aperture
Current probe opening	At least 15 mm

5.2.2 Voltage probe

Figure 10 shows a circuit which is used to make voltage measurements between a mains conductor and reference ground. The probe consists of a blocking capacitor C and a resistor such that the total resistance between line and earth is 1 500 Ω . The probe may also be used to make measurements on other lines and for certain applications its impedance may need to be increased to avoid excessive loading of high impedance circuits. An inductor may have to be connected across the input of the measuring apparatus, for safety reasons; its inductive reactive, X_C , to be much greater than R .

The insertion loss of voltage probes shall be calibrated in a 50 Ω system over the frequency range of 9 kHz to 30 MHz. The effect on the accuracy of measurement of any device which may be used for protection should either be less than 1 dB or be allowed for in calibration. Care shall be taken to ensure that the level of interference is accurately measured in the presence of the ambient noise to make the measurement meaningful.

The loop formed by the lead connected to the probe, the mains conductor tested and reference ground should be minimized to reduce the effects of any strong magnetic fields.

5.3 Absorbing clamp for use in the frequency range 30 MHz to 1 000 MHz

5.3.1 General

Absorbing clamps are suitable for the measurement of disturbance from some types of equipment depending on construction and size. The precise measuring procedure and its applicability is to be specified for each category of equipment. If the EUT itself (without connecting leads) approaches a 1/4 of a wavelength of the measuring frequency, direct cabinet radiation may occur.

The disturbance capability of an appliance with a mains lead being the only external lead may be taken as the power it could supply to its mains lead acting as a radiating antenna. This power is nearly equal to that supplied by the appliance to a suitable absorbing device placed around the lead at the position where the absorbed power is maximum. The absorbing device is known as the absorbing clamp or the ferrite clamp.

Equipment having external leads other than a mains lead can radiate disturbing energy from such leads, shielded or unshielded, in the same manner as radiation from the mains lead. Absorbing clamp measurements can be done on these leads also.

Radiation from leads at frequencies above 300 MHz, up to 1 000 MHz, may be measured with a suitable absorbing clamp. Such measurements could be of considerable use. However, it should be noted that substantial amount of radiation could emanate directly from the equipment.

5.3.2 Construction

The absorbing clamp shall consist of three parts as follows:

- a) a broadband RF current transformer;
- b) a broadband RF power absorber and impedance stabilizer for the lead under measurement;
- c) an absorbing sleeve or assembly of ferrite rings to reduce RF current on the surface of the coaxial cable from the current transformer to the measuring receiver.

Annex J describes the construction of some examples of absorbing clamps.

NOTE The transformer and the absorber described in a) and b) above respectively are maintained in fixed relative positions as close together as convenient. They may be constructed of split rings to avoid the necessity of disconnecting a fitted plug from the lead, but care should be taken to keep the air gap small.

5.3.3 Characteristics

The use of the absorbing clamp relies on a calibrating factor obtained by a specific calibration procedure, as described in annex H and figure 40. The absorbing clamp shall have a characteristic response of output power versus input power from the calibration signal generator, P_0 , that shows no pronounced resonance at any frequency.

The absorbing clamp shall present an impedance between 100 Ω and 250 Ω and not more than 20 % reactive when measured as shown in figure 40 with the signal generator and 10 dB attenuator replaced by an impedance measuring instrument. At each frequency of measurement the clamp is positioned along the lead, W, to obtain the maximum indication on the measuring receiver. It may be necessary to make a small adjustment in the position of the clamp to satisfy the reactance requirement. In a satisfactory clamp, the readjustment will not produce a significant change in the measured power.

Requirements for absorber attenuation are under consideration.

5.4 Disturbance analyzers

Disturbance analyzers are used for the automatic assessment of amplitude, rate and duration of discontinuous disturbances (clicks).

A “click” has the following characteristics:

- a) the QP amplitude exceeds the quasi-peak limit of continuous disturbance;
- b) the duration is not longer than 200 ms;
- c) and the spacing from a preceding or subsequent disturbance is equal to or more than 200 ms.

A series of short pulses shall be treated as a click when its duration, measured from the start of the first to the end of the last pulse, is not longer than 200 ms and conditions a) and c) are fulfilled.

The time parameters are determined from the signal which exceeds the IF reference level of the measuring receiver.

NOTE 1 Definition and assessment of clicks are in compliance with CISPR 14-1:2000.

NOTE 2 Current analyzers are designed to be used with a quasi-peak measuring receiver of the type which works with a limited internal signal level. As a result, such analyzers may not interface correctly with all receivers.

5.4.1 Fundamental characteristics

- a) The analyzer shall be equipped with a channel to measure the duration and spacing of discontinuous disturbances; the input of this channel shall be connected to the IF output of the measuring receiver. For these measurements, only the part of the disturbance has to be considered which exceeds the IF reference level of the receiver. The accuracy of duration measurements shall be not worse than $\pm 5\%$.

NOTE 1 The IF reference level is the corresponding value in the IF output of the measuring receiver to an unmodulated sinusoidal signal, which produces a quasi-peak indication equal to the limit for continuous disturbances.

- b) The analyzer shall be equipped with a channel to assess the quasi-peak amplitude of a disturbance.
- c) The amplitude in the quasi-peak channel shall be measured 250 ms after the last falling edge in the IF channel.
- d) The combination of both channels shall comply in all respects with the requirements of 4.1.
- e) The analyzer shall be capable of indicating the following information:
- the number of clicks of duration equal to or less than 200 ms;
 - the duration of the test in minutes;
 - the click rate;
 - the incidence of disturbances other than clicks which exceed the QP limit of continuous disturbance.

NOTE 2 An example of a disturbance analyzer is shown in form of a block diagram in Figure 11.

- f) For validation of the fundamental characteristics the analyzer has to pass the performance check with all the wave forms (test pulses) in Table 13.

Figure 12 presents in a graphical form all the waveforms listed in Table 13.

Figure Y.1 presents in a graphical form all the waveforms listed in Table Y.1 for the performance check of the exceptions from the definitions of a click according to 4.2.3 of CISPR 14-1.

**Table 13 – Disturbance analyzer performance test –
Test signals used for the check against the definition of a click**

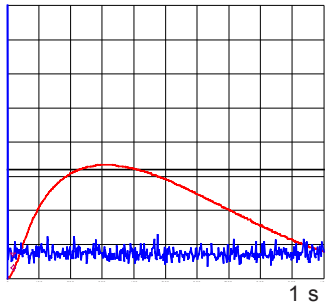
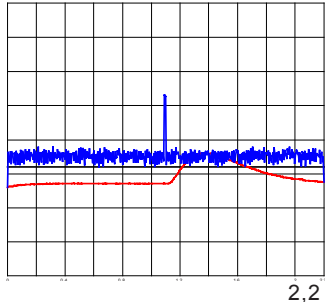
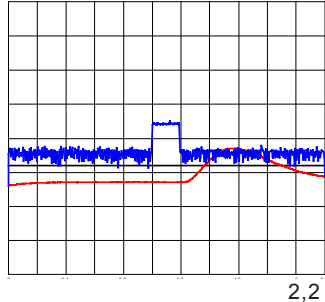
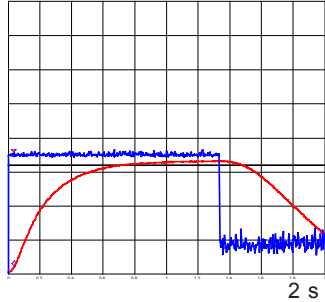
Test No.	Test signal parameters					Evaluation by the analyzer	Graphical presentation of the test signal measured in the IF-output and the associated QP signal relative to the reference indication of the measurement receiver
	1		2		3		
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses ^f adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (IF-output) ms		
	Pulse 1	Pulse 2	Pulse 1	Pulse 2			
1	1		0,11			1 click	
2 ^a	1		9,5			1 click	
3 ^a	1		190			1 click	
4	1		1 333 ^b			Other than click	

Table 13 (continued)

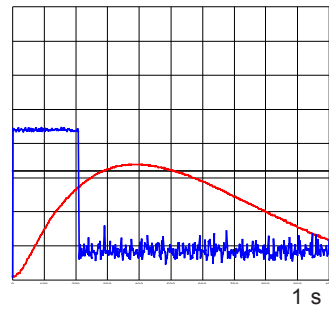
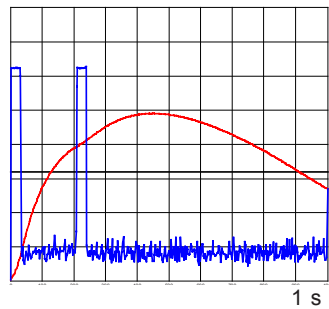
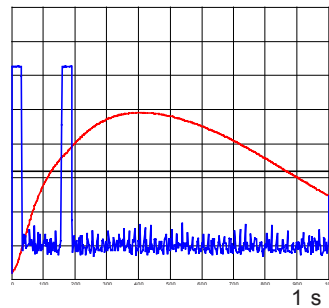
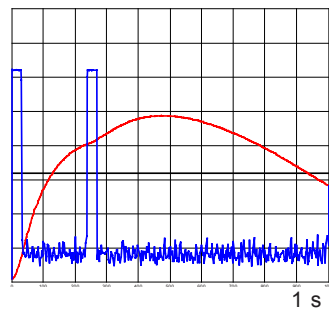
Test No.	Test signal parameters							
	1		2		3	4	5	
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses ^f adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (IF-output) ms	Evaluation by the analyzer	Graphical presentation of the test signal measured in the IF-output and the associated QP signal relative to the reference indication of the measurement receiver	
	Pulse 1	Pulse 2	Pulse 1	Pulse 2				
5	1		210			Other than click (210 ms)		
6	5	5	30	30	180	Other than click (240 ms)		
7	5	5	30	30	130	1 click		
8	5	5	30	30	210	2 clicks		

Table 13 (continued)

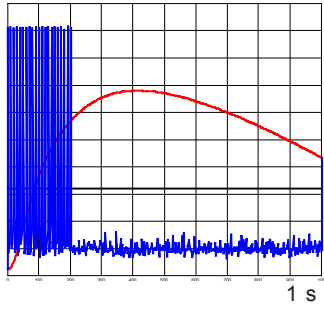
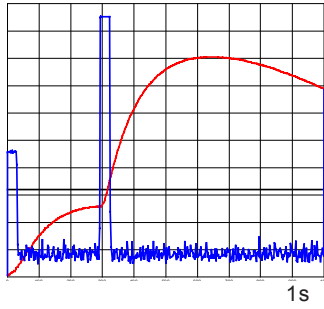
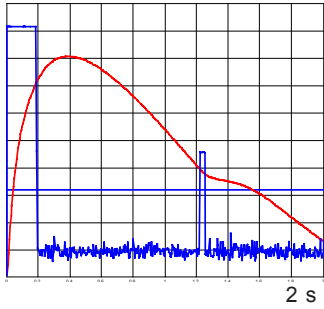
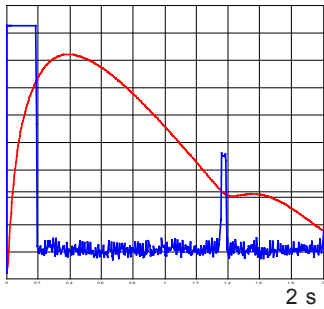
Test No.	Test signal parameters					Evaluation by the analyzer	Graphical presentation of the test signal measured in the IF-output and the associated QP signal relative to the reference indication of the measurement receiver
	1		2		3		
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses ^f adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (IF-output) ms		
	Pulse 1	Pulse 2	Pulse 1	Pulse 2			
9	1		0,11		Periodicity 10, min. 21 pulses	Other than click	
10	-2,5	25	30	30	265	1 click	
11	25	-2,5 ^c	190	30	1 034 ^e	2 clicks ^d	
12	25	-2,5 ^c	190	30	1 166 ^e	1 click	

Table 13 (continued)

^a	To be performed with background noise consisting of 200 Hz CISPR pulses at a level 2,5 dB below the quasi-peak threshold level. These pulses should be present commencing at least 1 s before the test pulse and lasting until at least 1 s after the test pulse. Observations: 1) The graphical representation is done with peak measurements of a very short hold time (<1 ms) of the test receiver which show the 200-Hz pulse. When the pulse-modulated sine wave arrives, the 200-Hz-pulse is no longer visible (as seen in the graph for test no. 3) but still present during the event of the click disturbance 2) The very narrow responses at the origin in the graphs are due to a firmware imperfection.
^b	The 1,333 s impulse checks the threshold of the analyzer for impulses, which are only 1 dB above the quasi-peak threshold level.
^c	These lower levels shall be set such that the intermediate frequency threshold is exceeded but the quasi-peak threshold is not exceeded
^d	If these two pulses were to be measured as separate disturbances, only one click would be registered.
^e	The correspondent values for the frequency range above 30 MHz are under consideration and will be revised after further investigations.
^f	The rise times of the pulses shall not be longer than 40 µs.

5.4.2 Test method for the validation of the performance check for the click analyzer

5.4.2.1 Basic requirements

The disturbance analyzer is connected to the quasi-peak measuring receiver and tuned to a convenient frequency.

A CW signal and a pulsed CW signal both at the tuned frequency of the receiver are required. A signal generated by CISPR pulse generator, as defined in Annex B, with a 200 Hz PRF covering the receiver bandwidth at the tuned frequency is also required for tests No. 2 and 3.

The pulsed CW signal source shall provide two independently variable pulses. The rise time of the pulses shall not be longer than 40 μ s. The pulse duration shall be variable between 110 μ s and 1,3 s and the amplitudes variable over a 44 dB range. Any background noise of the pulsed CW signal source shall be at least 20 dB below the reference level used in step a) in the test measured on the receiver's quasi-peak meter.

The test procedure is as follows:

- a) The CW signal is connected to the input of the measuring receiver used in conjunction with the disturbance analyzer. The amplitude of the CW signal is adjusted to bring the meter indication to the reference (zero) point on the meter scale of the measuring receiver equal to a value identical to the QP-limit for continuous disturbance. The receiver RF sensitivity (attenuator) control is adjusted to a level above the receiver noise but below the limit for continuous disturbance used as threshold in the IF channel. The corresponding level of the CW signal at the IF output of the receiver constitutes the IF reference level.
- b) The pulsed CW signal is connected to the input of the measuring receiver. For test number 2 and 3 the signal from the CISPR pulse generator is added to the pulsed CW signal. The parameters of the signal are given in Table 13. The amplitudes of the pulses shown in column 1 of Table 13 are adjusted individually relative to the indication of the limit (QP) for continuous disturbance used as threshold in the IF channel. The levels shall be relative to the respective RF and IF reference levels established in the previous paragraph.

5.4.2.2 Additional requirements

The test method is identical to the one described in 5.4.2.1.

The parameters of the signal are given in Table Y.1.

5.5 Antennas for measurement of radiated radio disturbance

The antenna and the circuits inserted between it and the measuring receiver shall not appreciably affect the overall characteristics of the measuring receiver. When the antenna is connected to the measuring receiver, the measuring system shall comply with the bandwidth requirements of clause 4 appropriate to the frequency band concerned.

The antenna shall be substantially plane polarized. It shall be orientable so that all polarizations of incident radiation can be measured. The height of the centre of the antenna above ground may have to be adjustable according to a specific test procedure.

For additional information about the parameters of broadband antennas see annex O.

5.5.1 Accuracy of field-strength measurements

The accuracy of field-strength measurement of a uniform field of a sine-wave shall be better than ± 3 dB when an antenna meeting the requirements of this subclause is used with a measuring receiver meeting the requirements of clause 4.

NOTE This requirement does not include the effect due to a test site.

5.5.2 Frequency range 9 kHz to 150 kHz

Experience has shown that, in this frequency range, it is the magnetic field component that is primarily responsible for observed instances of interference.

5.5.2.1 Magnetic antenna

For measurement of the magnetic component of the radiation, either an electrically-screened loop antenna of dimension such that the antenna can be completely enclosed by a square having sides of 60 cm in length, or an appropriate ferrite-rod antenna, may be used.

The unit of the magnetic field strength is $\mu\text{A/m}$ or, in logarithmic units, $20 \log(\mu\text{A/m}) = \text{dB}(\mu\text{A/m})$. The associated emission limit shall be expressed in the same units.

NOTE Direct measurements can be made of the strength of the magnetic component, in $\text{dB}(\mu\text{A/m})$ or $\mu\text{A/m}$ of a radiated field under all conditions, that is, both in the near field and in the far field. However, many field strength measuring receivers are calibrated in terms of the equivalent plane wave electric field strength in $\text{dB}(\mu\text{V/m})$, i.e. assuming that the ratio of the E and H components is 120π or 377Ω . This assumption is justified under far-field conditions at distances from the source exceeding one sixth of a wavelength ($\lambda/2\pi$), and in such cases the correct value for the H component can be obtained by dividing the E value indicated on the receiver by 377, or by subtracting 51,5 dB from the E level in $\text{dB}(\mu\text{V/m})$ to give the H level in $\text{dB}(\mu\text{A/m})$.

It should be clearly understood that the above fixed E and H ratio applies only under far-field conditions.

To obtain the reading of H ($\mu\text{A/m}$), the reading E ($\mu\text{V/m}$) is divided by 377Ω :

$$H (\mu\text{A/m}) = E (\mu\text{V/m}) / 377 \Omega \quad (1)$$

To obtain the reading of H $\text{dB}(\mu\text{A/m})$, 51,5 $\text{dB}(\Omega)$ is subtracted from the reading E $\text{dB}(\mu\text{V/m})$:

$$H \text{ dB}(\mu\text{A/m}) = E \text{ dB}(\mu\text{V/m}) - 51,5 \text{ dB}(\Omega) \quad (2)$$

The impedance $Z = 377 \Omega$, with $20 \log Z = 51,5 \text{ dB}(\Omega)$, used in the above conversions is a constant originating from the calibration of field strength measuring equipment indicating the magnetic field in $\mu\text{V/m}$ (or $\text{dB}(\mu\text{V/m})$).

5.5.2.2 Balance of antenna

The balance of the antenna shall be such that, when the antenna is rotated in a uniform field, the level in the cross-polarization direction is at least 20 dB below that in the parallel polarization direction.

5.5.3 Frequency range 150 kHz to 30 MHz

5.5.3.1 Electric antenna

For the measurement of the electric component of the radiation, either a balanced or an unbalanced antenna may be used. If an unbalanced antenna is used, the measurement will refer only to the effect of the electric field on a vertical rod antenna. The type of antenna used shall be stated with the results of the measurements.

Information pertaining to calculating the performance characteristics of a 1 m length monopole (rod) antenna and the characterization of its matching network is specified in Annex X.

Where the distance between the source of radiation and the antenna is 10 m or less, the total length of the antenna shall be 1 m. For distances greater than 10 m the preferred antenna length is 1 m, but in no case shall it exceed 10 % of the distance.

The unit of electric field strength shall be $\mu\text{V/m}$ or, in logarithmic units, $20 \log(\mu\text{V/m}) = \text{dB}(\mu\text{V/m})$. The associated emission limit shall be expressed in the same units.

5.5.3.2 Magnetic antenna

For the measurement of the magnetic component of the radiation, an electrically-screened loop antenna, as described in 5.5.2.1 shall be used.

Tuned electrically balanced loop antennas may be used to make measurements at lower field strengths than untuned electrically-screened loop antennas.

5.5.3.3 Balance of antenna

If a balanced electric or a magnetic antenna is used, it shall comply with the requirement of 5.5.2.2.

5.5.4 Frequency range 30 MHz to 300 MHz

5.5.4.1 Electric antenna

The reference antenna shall be a balanced dipole.

5.5.4.1.1 Balanced dipole

For frequencies 80 MHz or above, the antenna shall be resonant in length, and for frequencies below 80 MHz it shall have a length equal to the 80 MHz resonant length and shall be tuned and matched to the feeder by a suitable transforming device. Connection to the input of the measuring apparatus shall be made through a symmetric-asymmetric transformer arrangement.

5.5.4.1.2 Shortened dipole

A dipole shorter than a half wavelength may be used provided:

- a) the total length is greater than 1/10 of a wavelength at the frequency of measurement;
- b) it is connected to a cable sufficiently well matched at the receiver end to ensure a voltage standing wave ratio (v.s.w.r.) on the cable of less than 2.0 to 1. The calibration shall take account of the v.s.w.r.;
- c) it has a polarization discrimination equivalent to that of a tuned dipole (see 5.5.4.2). To obtain this, a balun may be helpful;
- d) for determination of the measured field strength, a calibration curve (antenna factor) is determined and used in the measuring distance (i.e., at a distance of at least three times the length of the dipole);

NOTE The antenna factors thus obtained should make it possible to fulfil the requirement of measuring uniform sine-wave fields with an accuracy not worse than ± 3 dB. Examples of calibration curves are given in figure 13 which shows the theoretical relation between field strength and receiver input voltage for a receiver of input impedance of $50\ \Omega$, and for various l/d ratios. On these figures, the balun is considered as an ideal 1:1 transformer. It should be noted, however, that these curves do not account for the losses of the balun, the cable and any mismatch between the cable and the receiver.

- e) in spite of the sensitivity loss of the field-strength meter due to a high antenna factor attributed to the shortened length of the dipole, the measuring limit of the field-strength meter (determined for example by the noise of the receiver and the transmission factor of the dipole) shall remain at least 10 dB below the level of the measured signal.

5.5.4.1.3 Broadband antenna

A broadband antenna may be used, provided that it meets the requirements given in 5.5.5.2 for a complex antenna.

5.5.4.2 Balance of antenna

5.5.4.2.1 Introduction

In radiated emission measurements, common-mode (CM) currents may be present on the cable attached to the receiving antenna (the antenna cable). In turn, these CM currents create EM fields which may be picked up by the receiving antenna. Consequently, the radiated emission measuring results may be influenced.

The major contributions to the antenna cable CM current stem from:

- a) the electric field generated by the EUT, if that field has a component parallel to the antenna cable; and
- b) the conversion of the differential mode (DM) antenna signal (the desired signal) into a CM signal by the imperfection of the balun of the receiving antenna.

This subclause considers the balun contribution. Contribution a) is under consideration (see last sentence of NOTE 1 of 5.5.4.2.2).

In general, log-periodic dipole array antennas do not exhibit significant DM/CM conversion and the following check applies to dipoles, biconical antennas and bicone/log hybrid antennas.

5.5.4.2.2 Balun DM/CM conversion check

The following method describes the measurement of two voltages, U_1 and U_2 , in the frequency range for which the receiving antenna is to be used. The ratio of these voltages, both expressed in identical units (e.g., dBµV), is a measure for the DM/CM conversion.

- 1) Set the receiving antenna under test vertically polarized with its centre at a height of 1,5 m above the ground plane. Lay the cable horizontally for $1,5 \text{ m} \pm 0,1 \text{ m}$ behind the rear active element of the antenna and then drop it vertically by a height of at least 1.5 m to the ground plane.
- 2) Place a second (transmitting) antenna vertically polarized at a horizontal distance of 10 m from the centre of the antenna under test with its tip 0,10 m from the ground plane. If the range of the site used for emission testing is 3 m, do this check using a distance of 3 m (if the conversion check has already been made at 10 m distance and shows a change of less than $\pm 0,5 \text{ dB}$, it is not necessary to take a separate measurement at 3 m). The specification of the transmitting antenna shall include the frequency range of the antenna under test.
- 3) Connect the transmitting antenna to a signal source, for example, a tracking generator, set the level of that generator in such a way that, over the frequency range of interest, the signal-to-ambient noise at the receiver is larger than 10 dB.
- 4) Record the voltage U_1 at the receiver over the frequency range of interest.
- 5) Invert the receiving antenna (rotate that antenna through 180°) without changing anything else in the set-up, in particular the receiving antenna cable, and without changing the setting of the signal source.
- 6) Record the voltage U_2 at the receiver over the frequency range.
- 7) The DM/CM conversion is sufficiently low if $|20 \log (U_1/U_2)| < 1 \text{ dB}$.

NOTE 1 If the DM/CM conversion criterion is not met, ferrite rings around the antenna cable may reduce the DM/CM conversion. The addition of ferrites on the antenna cable may also be used to verify whether contribution a) has a non-negligible effect. Repeat the test with four ferrites spaced approximately 20 cm apart. If the criterion is met by using these rings, they shall be present in the actual emission measurement. Likewise, the interaction with the cable can be reduced by extending the cable several metres behind the antenna before dropping to ground.

NOTE 2 If the receiving antenna is to be used in a fully anechoic chamber, the DM/CM check may be performed in that room with the receiving antenna at its usual location and the transmitting antenna in the centre of the test volume of that room. The room must comply with the $\pm 4 \text{ dB}$ criterion.

NOTE 3 The measuring site of which the ground plane forms a part, or the fully anechoic room, should comply with their respective NSA requirements.

NOTE 4 The horizontal distance of 1,5 m over which the antenna cable runs horizontally behind the centre of the antenna shall be kept as a minimum during actual vertically polarized radiated emissions measurements.

NOTE 5 It is not necessary to define a test set-up strictly because this effect is in large part due to the interaction of the antenna and the part of input cable that lies parallel to the antenna elements. There is a much smaller effect which is dependent on the uniformity of the field incident on the antenna in normal EMC set-ups on an OATS or in a fully anechoic room.

NOTE 6 For baluns which have the receive cable connector mounted on the side (90° to the antenna boom), a right angle connector should be used to reduce the movement of the cable.

5.5.4.3 Cross-polar performance of antenna

When an antenna is placed in a plane-polarized electromagnetic field, the terminal voltage when the antenna and field are cross-polarized shall be at least 20 dB below the terminal voltage when they are co-polarized. It is intended that this test apply to log-periodic dipole array (LPDA) antennas for which the two halves of each dipole are in echelon. The majority of testing with such antennas is above 200 MHz, but the requirement applies below 200 MHz. This test is not intended for in-line dipole and biconical antennas because a cross-polar rejection greater than 20 dB is intrinsic to their symmetrical design. Such antennas and horn antennas must have a cross-polar rejection greater than 20 dB and a type test by the manufacturer should confirm this.

In order to achieve quasi-free space conditions, a high-quality anechoic chamber or towers of sufficient height above ground on an outdoor range can be used. To minimize ground reflections set the antennas vertically polarized. A plane wave shall be set up at the antenna under test. The separation between the centre of the antenna under test and the source antenna shall be greater than one wavelength.

NOTE 1 A good-quality site is needed to set up a plane wave at the antenna under test. The cross-polar discrimination afforded by the plane wave can be proven by transmitting between a pair of horn antennas or open-ended waveguides and checking that the combination of site error and inherent cross-polar performance of one horn antenna yields a suppression of the horizontal component by more than 30 dB. If the site errors are very low and if the horn antennas have identical performance, the cross-polar performance of one horn is approximately 6 dB lower than the combined cross-polar coupling of the pair of horns.

An interfering signal 20 dB lower in level than the desired signal gives a maximum error on the desired signal of $\pm 0,9$ dB. The maximum error occurs when the cross-polar signal is in phase with the co-polar signal. If the cross-polar response of the LPDA is worse than 20 dB, the operator must calculate the uncertainty and declare it with the result, for example a cross-polar level of 14 dB implies a maximum uncertainty of +1,6 dB to -1,9 dB. Take the larger value and assume a U-shaped distribution when calculating the standard uncertainty.

To add a signal of 0 dB to another of -14 dB, first convert to relative voltages by dividing by 20 and taking the anti-log. Then add the smaller signal to the unity signal. Take the log and multiply by 20. The result is the positive decibel error. Repeat, but subtracting the smaller signal from the unity signal to give the negative decibel error.

For the purpose of calculating the uncertainty of the result of a radiated emission, if the signal level measured in one polarization exceeds the signal measured in the orthogonal polarization by 6 dB or more, then an LPDA whose cross-polar discrimination is only 14 dB will have been deemed to have met the specification of 20 dB. If the difference between the VP and HP signal levels is less than 6 dB, additional uncertainty must be calculated if the sum of this difference and the cross-polarization is less than 20 dB.

5.5.5 Frequency range 300 MHz to 1 000 MHz

5.5.5.1 Electric antenna

If a dipole antenna is used, it shall meet the requirements of 5.5.4.1.1 and 5.5.4.2.

5.5.5.2 Complex antenna

Since, at the frequencies in the range 300 MHz to 1 000 MHz, the sensitivity of the simple dipole antenna is low, a more complex antenna may be used. Such antenna shall be as follows:

- a) The antenna shall be substantially plane polarized. This shall be checked in the same manner as for the balance of a simple dipole antenna.
- b) The main lobe of the radiation pattern of the antenna shall be such that the response in the direction of the direct ray and that in the direction of the ray reflected from the ground do not differ by more than 1 dB.

To ensure this condition, the total vertical angular aperture 2φ of the measuring antenna, within which the antenna gain is within 1 dB of its maximum, shall be such that:

- 1) if the measuring antenna is maintained in a horizontally direct position:

$$\varphi > \tan^{-1} [(h_1 + h_2)/d]$$

- 2) if the measuring antenna is tilted towards earth in the optimum position (so that direct and reflected rays are included within the aperture 2φ):

$$2\varphi > \tan^{-1} [(h_1 + h_2)/d] - \tan^{-1} [(h_1 - h_2)/d]$$

where

h_1 is the measuring antenna height;

h_2 is the height of the device under test;

d is the horizontal distance between the measuring antenna and the device under test.

The pattern of the antenna shall be checked in the horizontal plane while orienting it for vertical polarization. It shall be assumed that the pattern and, in particular, the angular aperture 2φ is the same when horizontally polarized as when measured with the vertical polarization.

It is essential that the variation of the effective distance of the antenna from the source and its gain with frequency be taken into account.

- c) The voltage standing-wave ratio of the antenna with the antenna feeder connected and measured from the receiver end shall not exceed 2,0 to 1.
- d) A calibration factor shall be given making it possible to fulfil the requirements of 5.5.1.

5.5.6 Frequency range 1 GHz to 18 GHz

Radiated emissions measurements above 1 GHz shall be made using calibrated, linearly polarized antennas. These include double-ridged guide horns, rectangular wave guide horns, pyramidal horns, optimum gain horns and standard gain horns. The "beam" or main lobe of the pattern of any antenna used shall be large enough to encompass the EUT when located at the measuring distance, or provisions shall be made for "scanning" the EUT to locate the direction or source of its radiated emissions. The width of the main lobe is defined as the 3 dB beamwidth of the antenna, and information enabling the determination of this parameter should be given in the antenna documentation. The aperture dimensions of these horn antennas shall be small enough so that the measurement distance R_m in metres is equal to or greater than the following minimum distance:

$$R_m \geq D^2/2\lambda$$

where

D is the largest dimension of the aperture in metres of the antenna;

λ is the free space wavelength in metres at the frequency of measurement.

In case of dispute, measurements made with a standard gain horn antenna or a similar precisely calibrated horn antenna shall take precedence.

NOTE Any calibrated, linearly polarized antenna, e.g. a log periodic dipole array, may be used to make these measurements. The gain of many antennas other than horn antennas in this frequency range may be inadequate if the antennas are used with spectrum analyzers or older radio noise meters. The tester shall assure that the overall measurement sensitivity is at least 6 dB below the applicable limit at the measurement distance in use, and that any means used to improve sensitivity, e.g. a preamplifier, does not cause distortion, spurious signals, or other overload problems. Since a log periodic dipole array has a much wider beamwidth than a horn antenna, reflections from the ground plane may cause significant error in measurements that are made with a log periodic dipole array.

5.5.7 Special antenna arrangements

5.5.7.1 Loop antenna system

In the frequency range 9 kHz to 30 MHz the interference capability of the magnetic field component of the radiation of a single (EUT) can be determined by using a special loop antenna system (LAS). In the LAS, this capability is measured in terms of the currents induced by the magnetic field in the loop antennas of the LAS. The LAS allows indoor measurements.

The LAS consists of three circular, mutually perpendicular large-loop antennas (LLAs), having a diameter of 2 m, supported by a non-metallic base. A full description of the LAS is given in annex P.

The EUT is positioned in the centre of the LAS. The maximum dimensions of the EUT are limited so that the distance between the EUT and an LLA is at least 0,20 m. Guidelines for the routing of signal cables are given in clause P.3, note 2 and figure P.6. Cables should be routed together and leave the loop volume in the same octant of the cell and no closer than 0,4 m to any of the LAS loops.

The three mutually perpendicular LLAs allow measurement of the interference capability of all polarizations of the radiated field with the prescribed accuracy, and without rotation of the EUT or changing the orientation of the LLAs.

Each of the three LLAs shall comply with the validation requirements given in clause P.5.

NOTE Circular LLAs having a diameter different from the standardized diameter of 2 m may be used, provided their diameter $D \leq 4$ m and the distance between the EUT and a LA is at least $0,10(D)$ m. Correction factors for non-standardized diameters are given in clause P.6.

5.6 Test sites for measurement of radio disturbance field strength for the frequency range of 30 MHz to 1 000 MHz

An environment is required which assures valid, repeatable measurement results of disturbance field strength from equipment. For equipment which can only be tested in its place of use, different provisions have to be utilized.