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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

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FOREWORD

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International Standard CISPR 16-1-1 has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

This consolidated version of CISPR 16-1-1 consists of the second edition (2006) [documents CISPR/A/642/FDIS and CISPR/A/651/RVD] and its amendment 1 (2006) [documents CISPR/A/647/CDV and CISPR/A/686/RVC].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 2.1.

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The CISPR 16 series, published under the general title *Specification for radio disturbance and immunity measuring apparatus and methods,* consists of Parts 1, 2, 3 and 4, each of which is further subdivided into parts:

– measurement instrumentation specifications are given in the five parts of CISPR 16-1;
– methods of measurement are covered in the four parts of CISPR 16-2;
– various reports with further information and background on CISPR and radio disturbances in general are given in CISPR 16-3;
– information related to uncertainties, statistics and limit modelling is contained in CISPR 16-4.

CISPR 16-1 consists of the following parts, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods – Radio disturbance and immunity measuring apparatus:*

- Part 1-1: Measuring apparatus
- Part 1-2: Ancillary equipment – Conducted disturbances
- Part 1-3: Ancillary equipment – Disturbance power
- Part 1-4: Ancillary equipment – Radiated disturbances
- Part 1-5: Antenna calibration test sites for 30 MHz to 1 000 MHz

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 1-1: Radio disturbance and immunity measuring apparatus – 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.

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. Uncertainties, statistics and limit modelling are covered in Part 4 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.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1 (1997)
Amendment 2 (1998)

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

CISPR 14-1:2005, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

CISPR 16-3:2003, *Specification for radio disturbance and Immunity measuring apparatus and methods – Part 3: CISPR technical reports*

BIPM / IEC / IFCC / ISO / IUPAC / IUPAP / OIML:1993, *International vocabulary of basic and general terms in metrology*

3 Terms and definitions

For the purpose of this document, the following definitions apply. Also see IEC 60050(161) and the *International vocabulary of basic and general terms in metrology.*

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}

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

where

$A(t)_{max}$ 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,

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

where

B_6 and B_3 are respectively the bandwidths at the –6 dB and –3 dB points (see Clause A.2 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:

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

NOTE Spectral density (D) is related to impulse area and expressed in µV/MHz or dB(µV/MHz). For rectangular impulses of pulse duration T at frequencies $f << 1/T$, the relationship D (µV/MHz) = $\sqrt{2} \times 10^6$ IS (µVs) 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 0,63 *D*. 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 0,37 *D* is the discharge time constant of the detector.

3.6
mechanical time constant of a critically damped indicating instrument
T_M

$$T_M = T_L / 2\pi$$

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:

a) The period of free oscillation having been adjusted to $2\pi T_M$, damping is added so that $\alpha T = 0{,}35\alpha_{max}$.
b) When the period of oscillation cannot be measured, the damping is adjusted to be just below critical such that the overswing 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 *Va* is the vector voltage between one of the mains terminals and earth and *Vb* is the vector voltage between the other mains terminal and earth, the symmetric voltage is the vector difference (*Va*-*Vb*)

3.9
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 section of CISPR 16

4 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 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.

4.2 Fundamental characteristics

The responses to pulses as specified in 4.4 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	0,20	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 4.4

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 resistance source impedance.

4.4 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.

4.4.1 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 ±1,5 dB shall be permitted on the sine-wave voltage level.

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

4.4.2 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.

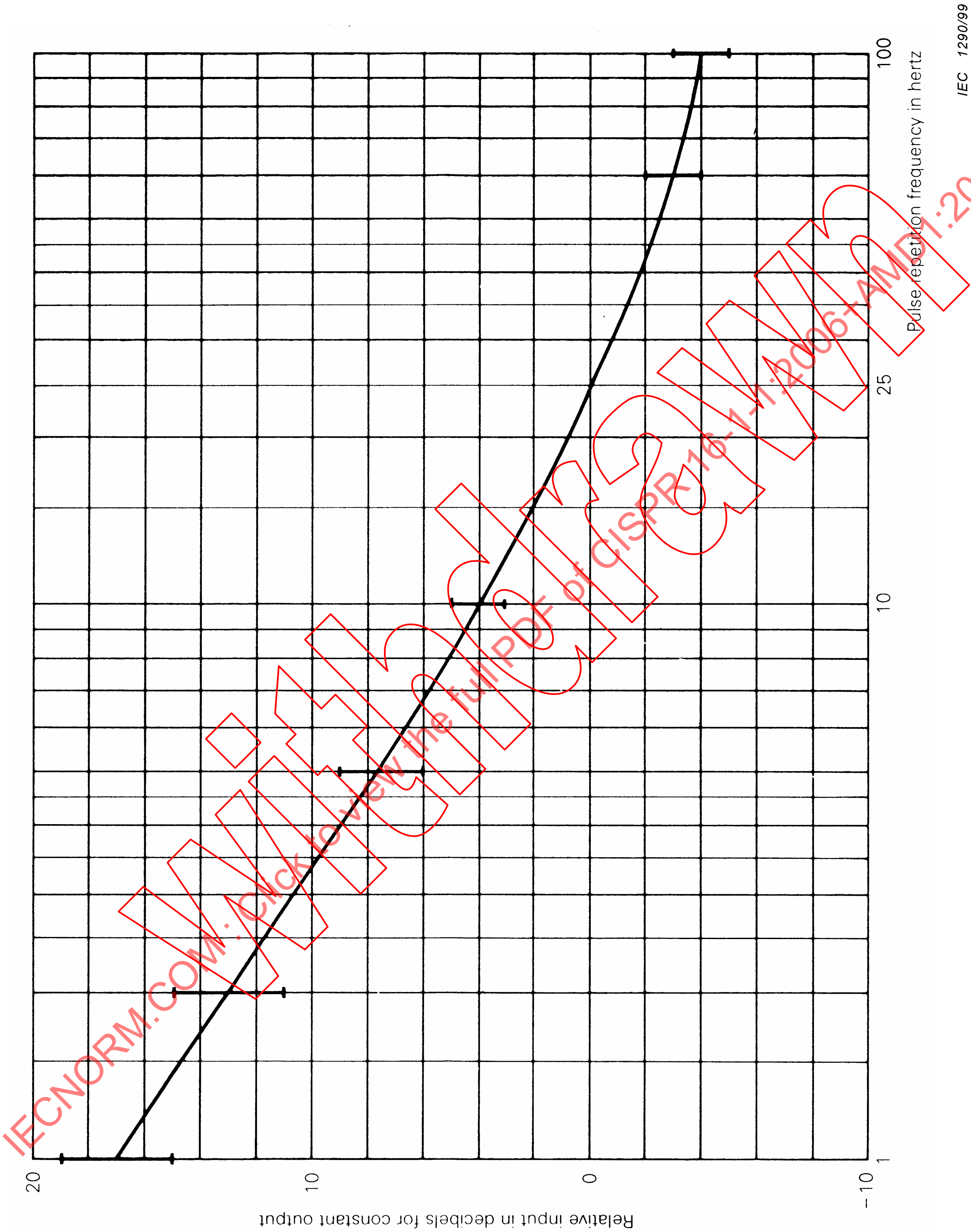
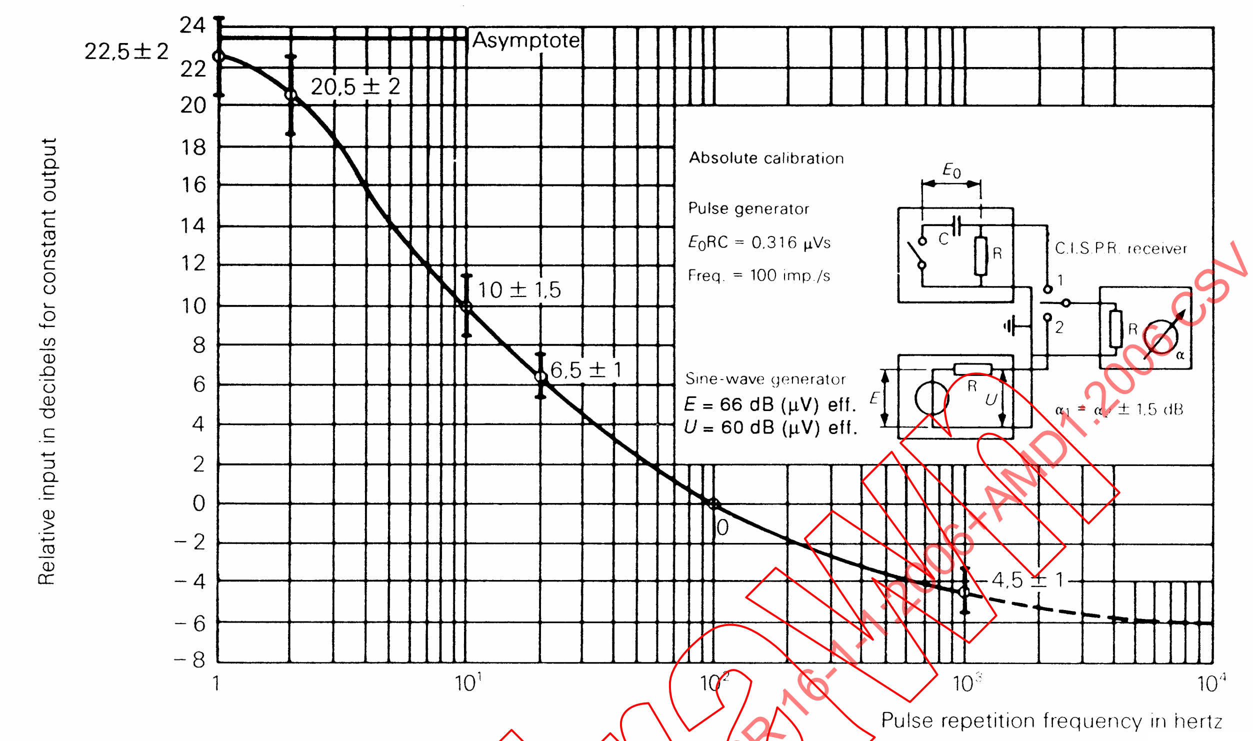
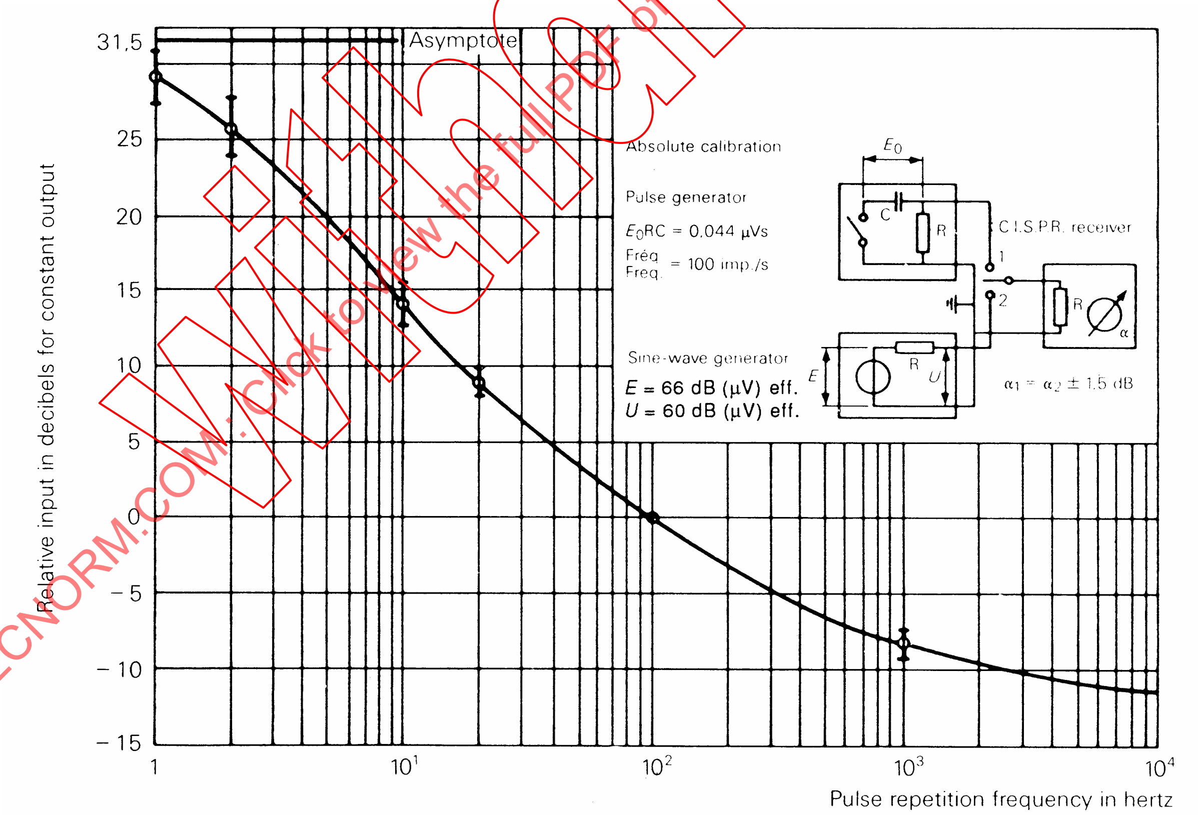


Figure 1a – Pulse response curve (Band A)



IEC 1291/99

Figure 1b – Pulse response curve (Band B)



IEC 1292/99

Figure 1c – Pulse response curve (Bands C and D)

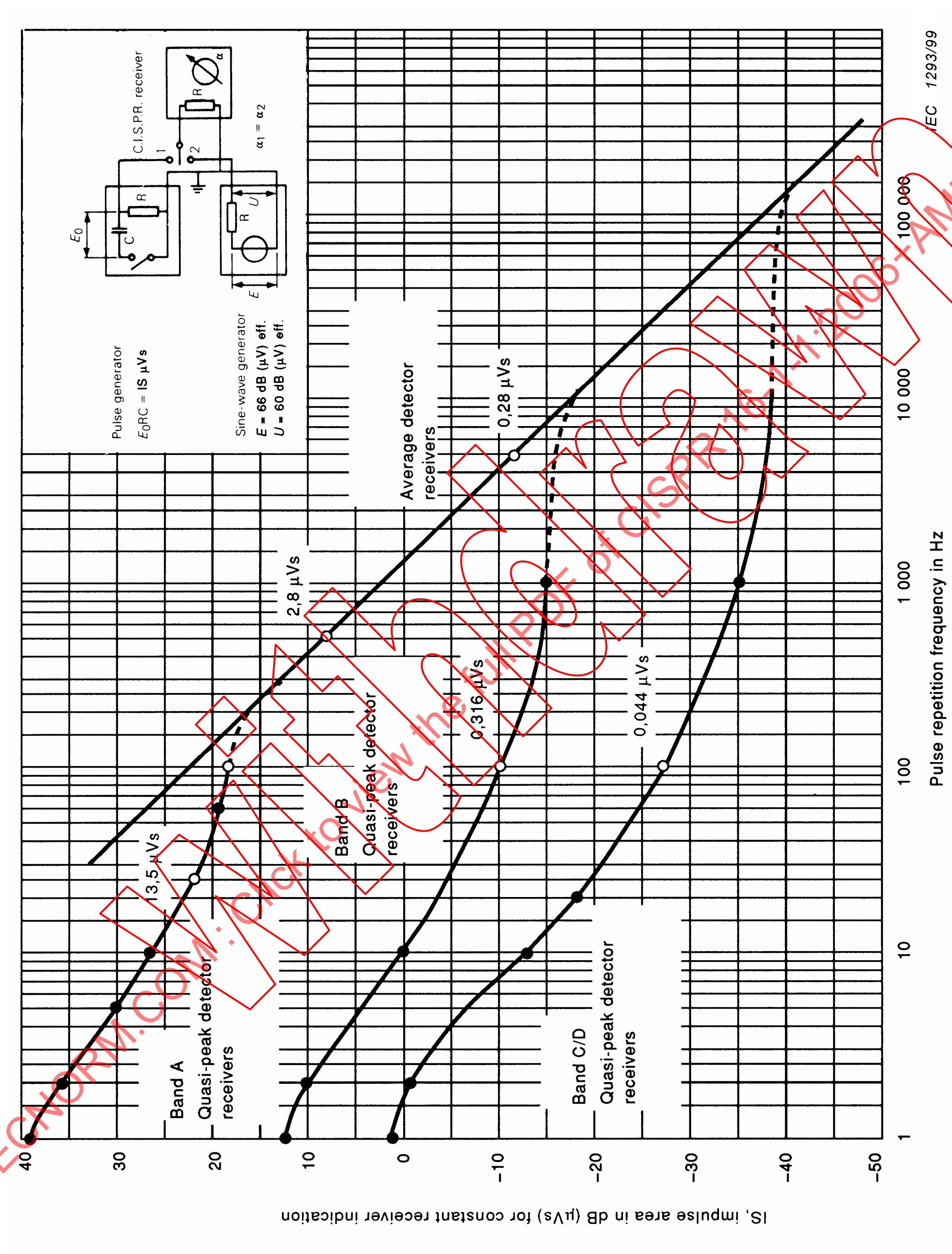


Figure 1d – Theoretical pulse response curve of quasi-peak detector receivers and average detector receiver (see 6.4.2)

Figure 1 – Pulse response curves

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 ± 1,0	–8,0 ± 1,0	–8,0 ± 1,0
100	–4,0 ± 1,0	0 (ref.)	0 (ref.)	0 (ref.)
60	–3,0 ± 1,0	–	–	–
25	0 (ref.)	–	–	–
20	–	+6,5 ± 1,0	+9,0 ± 1,0	+9,0 ± 1,0
10	+4,0 ± 1,0	+10,0 ± 1,5	+14,0 ± 1,5	+14,0 ± 1,5
5	+7,5 ± 1,0	–	–	–
2	+13,0 ± 2,0	+20,5 ± 2,0	+26,0 ± 2,0	+26,0 ± 2,0*
1	+17,0 ± 2,0	+22,5 ± 2,0	+28,5 ± 2,0	+28,5 ± 2,0*
Isolated pulse	+19,0 ± 2,0	+23,5 ± 2,0	+31,5 ± 2,0	+31,5 ± 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 5.4, 6.4.1 and 7.4.1.

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(μVs) corresponding to the open-circuit sine-wave voltage of 66 dB(μV) r.m.s. The indication on a measuring receiver with an input matched to the calibrating generators will then be 60 dB(μV). 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.

4.5 Selectivity

4.5.1 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.

4.5.2 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.

4.5.3 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.

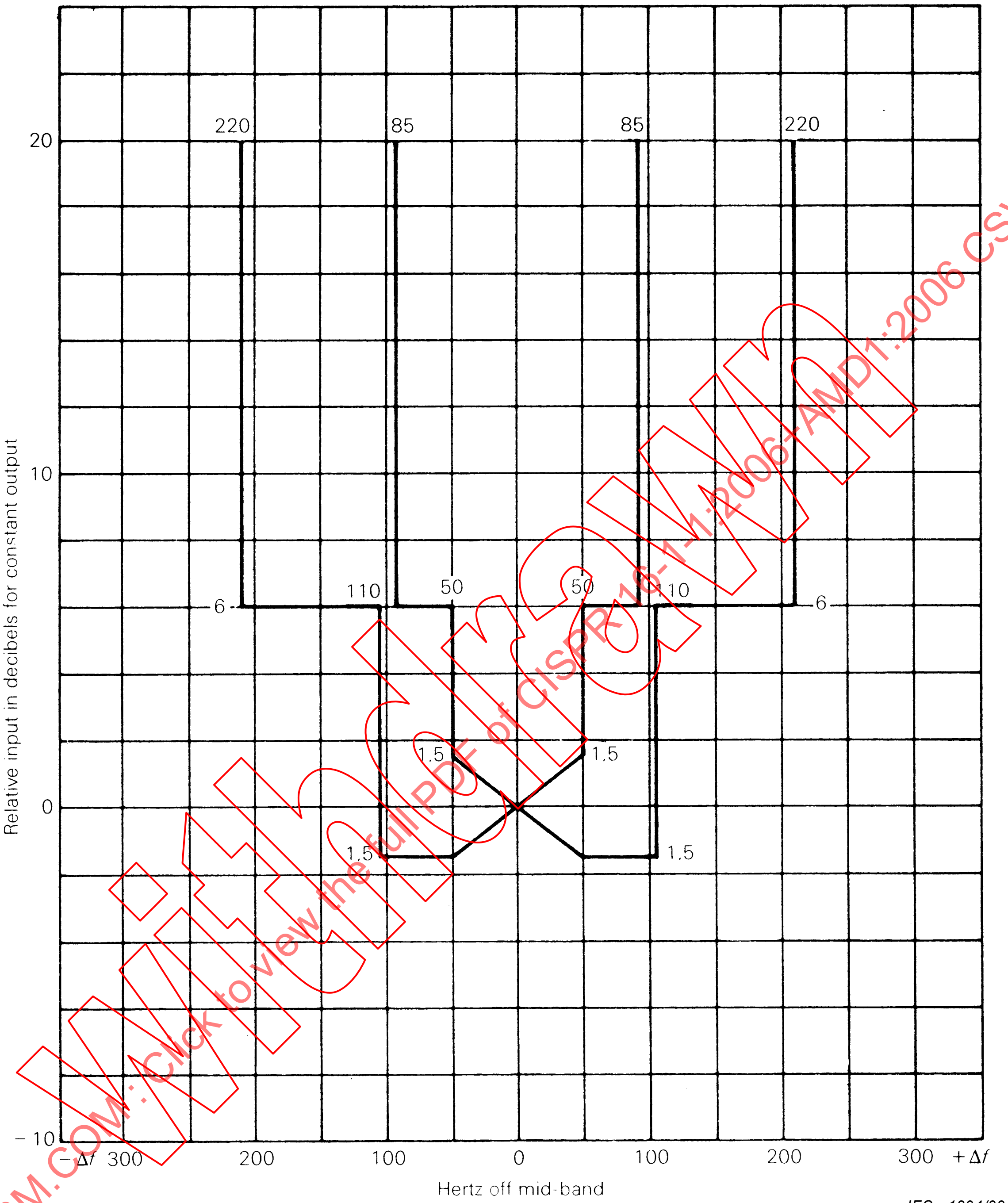


Figure 2a – Limits of overall selectivity – pass-band (see 4.5.1, 5.5, 6.5, 7.5) (Band A)

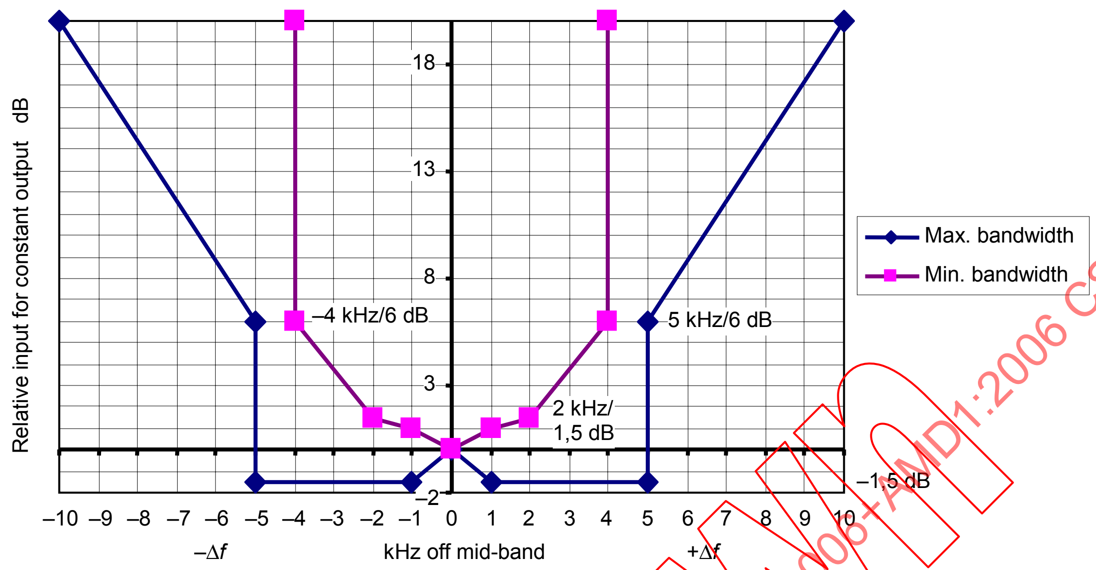


Figure 2b – Limits of overall selectivity – pass band (see 4.5.1, 5.5, 6.5, 7.5) (Band B)

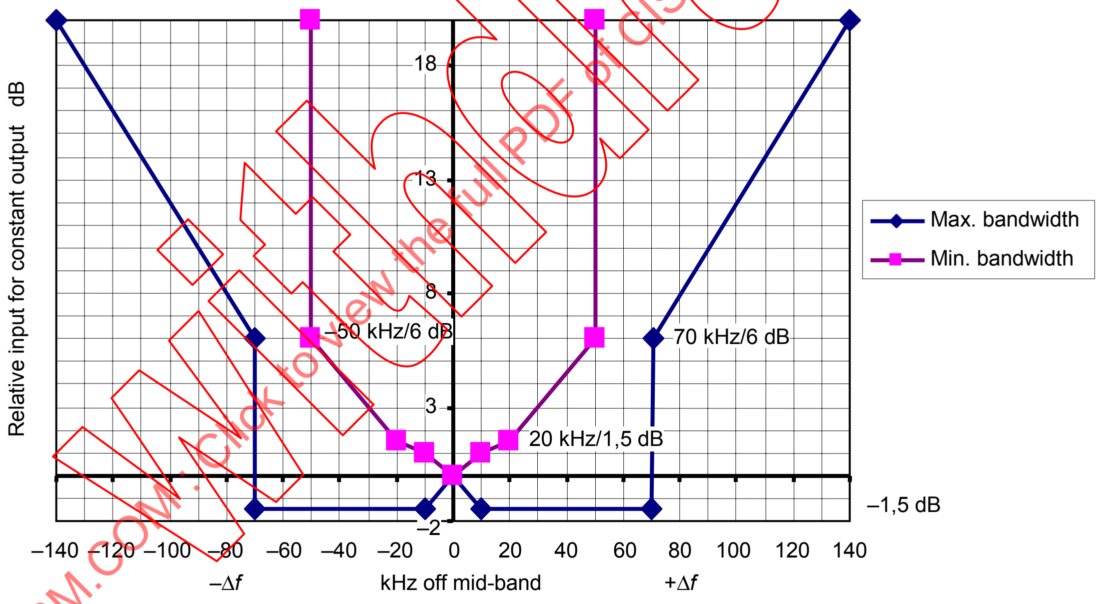


Figure 2c – Limits of overall selectivity – passband (see 4.5.1, 5.5, 6.5, 7.5) Bands (C and D)

Figure 2 – Limits of overall selectivity

4.5.4 Other spurious responses

The ratio of the input sine-wave voltage at frequencies other than those specified in 4.5.2 and 4.5.3 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;

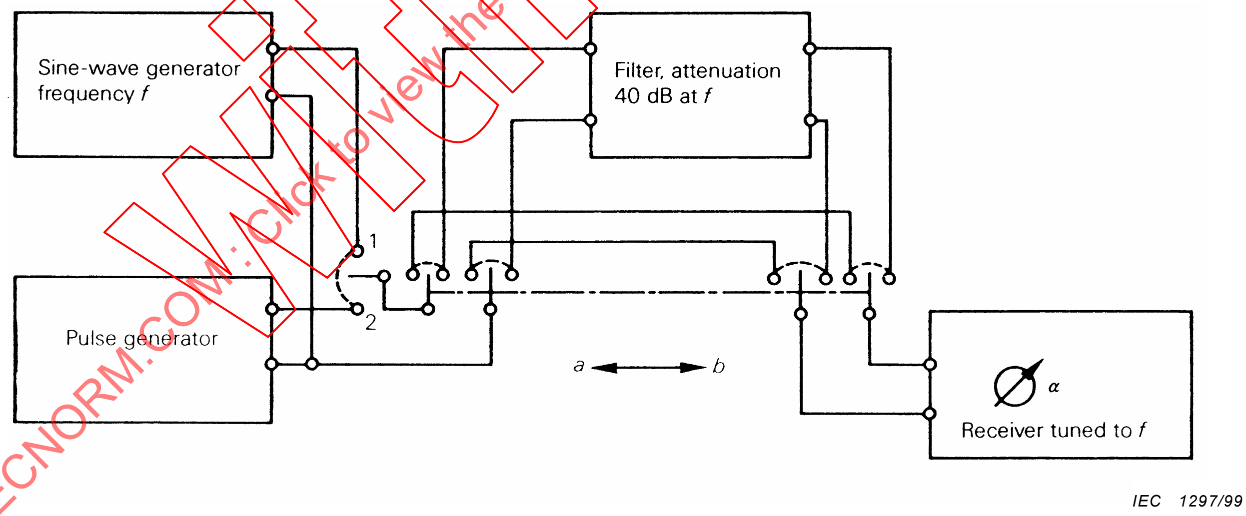
f_o is the tuned frequency.

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 4.7.2.

4.6 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.



Responses:

$\alpha_{1a} = \alpha_{2a}$

$\alpha_{1b} = \alpha_{1a} - 40$ dB

$\alpha_{2b} = \alpha_{2a} - 36$ dB

Figure 3 – Arrangement for testing intermodulation effects

Table 4 – Bandwidth characteristics for intermodulation 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.

4.7 Limitation of receiver noise and internally generated spurious signals

4.7.1 Random noise

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

NOTE The point where the background noise causes an error of 1 dB can be found by applying a signal, *S*, such that the meter indication is much larger (e.g.40 dB) than the noise level *N*. By reducing the signal level *S*, the meter indication will reach a point, S_1, where ($S_1 + N$) deviates by 1 dB from the linear characteristic.

4.7.2 Continuous wave

Where more than one intermediate frequency is used, the existence of spurious responses as described in the note to 4.5.4 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 4.7.1 when tested as described in 4.7.1, except that the attenuation in the intermediate stages shall be introduced after the last mixer stage.

4.8 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 3.9.

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.

4.8.1 Limitation of radio-frequency emissions from the measuring receiver

4.8.1.1 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 µV across 50 Ω.

4.8.1.2 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.

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).

4.9 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.

5 Measuring receivers with peak detector for the frequency range 9 kHz to 18 GHz

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

Spectrum analyzers, that meet the requirements of this clause can be used for compliance measurements.

5.1 Input impedance

The input port of the measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the nominal input impedance shall be 50 Ω with a VSWR not to exceed the values in Table 5.

Table 5 – VSWR requirements for receiver input impedance

Frequency range	RF attenuation dB	VSWR
9 kHz to 1 GHz	0	2,0 to 1
9 kHz to 1 GHz	≥10	1,2 to 1
1 GHz to 18 GHz	0	3,0 to 1
1 GHz to 18 GHz	≥10	2,0 to 1

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

5.2 Fundamental characteristics

5.2.1 Bandwidth

For all types of broadband disturbance, the actual value of the bandwidth shall be stated when the disturbance level is quoted and the bandwidth is within the values in Table 6.

Table 6 – Bandwidth requirements

Frequency range	Bandwidth B_6	Reference BW
9 kHz to 150 kHz (Band A)	100 Hz to 300 Hz [a]	200 Hz (B_6)
0,15 MHz to 30 MHz (Band B)	8 kHz to 10 kHz [a]	9 kHz (B_6)
30 MHz to 1000 MHz (Bands C and D)	100 kHz to 500 kHz [a]	120 kHz (B_6)
1 GHz to 18 GHz (Band E)	300 kHz to 2 MHz [a]	1 MHz [b] (B_{imp})

[a] 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 "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 may introduce an error. In case of dispute, data measured with the reference bandwidth shall take precedence.

[b] The bandwidth selected shall be defined as the impulse bandwidth of the measuring receiver with a tolerance of ±10% .

5.2.2 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 ratio of discharge time constant to charge time constant shall be equal to or greater than the following values:

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

d) $1,34 \times 10^8$ in the frequency range 1 GHz to 18 GHz

If the test receiver has a peak-hold capability, the hold time shall be adjustable to values between 30 ms and 3 s.

NOTE For receivers that use peak hold (and forced discharge after the hold time) or digital peak detection techniques, the requirement on the charge/discharge time constants ratio is not relevant. A maximum-hold function of the display may be used for signals with time-varying amplitudes.

If a spectrum analyzer is used for peak measurements, the video bandwidth (B_{video}) shall be set to a value greater than or equal to the resolution bandwidth (B_{resol}). For peak measurements, the result can be read from the spectrum analyzer display with the detector operating either in the linear or logarithmic mode.

5.2.3 Overload factor

For peak measuring receivers, the overload factor does not need to be as high as it is for other types of measuring receivers. For most direct-reading detectors, the overload factor need be only a little larger than unity. The overload factor shall be adequate for the time-constants used (see 5.2.2).

5.3 Sine-wave voltage accuracy

The accuracy of sine-wave voltage measurement shall be better than ±2 dB (±2,5 dB above 1 GHz) when fed with a sine-wave signal at a 50 Ω resistive source impedance.

5.4 Response to pulses

Up to 1 000 MHz, the response of the measuring receiver to pulses with impulse area $1,4/B_{imp}$ mVs (where B_{imp} is in hertz) emf at 50 Ω source impedance shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an emf with rms value of 2 mV [66 dB(μV)]. The source impedances of both the pulse generator and the signal generator shall be the same. The pulses shall have a uniform spectrum according to Table 2. A tolerance of ±1,5 dB is permitted in the sine-wave voltage level, and this is a requirement for all pulse repetition frequencies for which no overlapping pulses occur at the output of the IF amplifier.

NOTE 1 Annexes B and C describe methods for determining the output characteristics of pulse generators for use in testing for 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 7.

Table 7 – Relative pulse response of peak and quasi-peak measuring receivers for the same bandwidth (frequency range 9 kHz to 1 000 MHz)

Frequency	*IS* mVs	B_{imp} Hz	Ratio peak/quasi-peak (dB) for pulse repetition rate 25 Hz	Ratio peak/quasi-peak (dB) for pulse repetition rate 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
NOTE The pulse response is based on the use of the reference bandwidth only (see Table 6).				

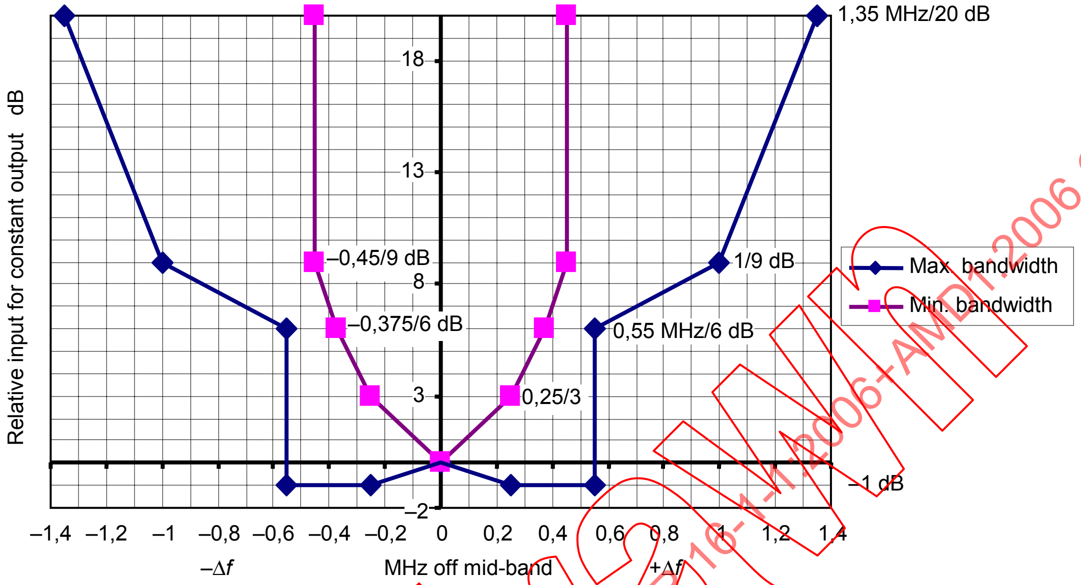
Above 1 GHz, the required impulse strength is defined using a pulse-modulated carrier at the frequency of test, since pulse generators with a uniform spectrum up to 18 GHz are not feasible. (See Clause E.6)

5.5 Selectivity

Since the bandwidth requirements stated in 5.2.1 allow variations from the bandwidths shown in Figures 2a, 2b and 2c, these selectivity curves apply to peak measuring receivers in regard to shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in Figure 2a.

The requirements in 4.5.2, 4.5.3 and 4.5.4 apply.

The curve representing the overall selectivity of the measuring receiver reference bandwidth for band E shall lie within the limits of Figure 8.



NOTE 1 The limits for the impulse bandwidth cannot be shown in the diagram, as the related filter attenuation depends on the type of the filter. Therefore bounds for the 6-dB and the 9-dB bandwidths have been given for orientation.

NOTE 2 The limits for the overall selectivity have been derived from equipment being in use at the time of introduction of the selectivity requirement.

Figure 8 – Limits for the overall selectivity – pass band (Band E)

5.6 Intermodulation effects, receiver noise, and screening

For the frequency range below 1 GHz, the requirements stated in 4.6, 4.7 and 4.8 apply. Subclauses 4.7 and 4.8.1 apply also for Band E.

In addition, the following applies for Band E:

- Requirements for intermodulation effects are under consideration.
- Preselection filter for Band E: when measuring low level spurious signals in the presence of a strong fundamental signal for certain equipment-under-test, insert a filter at the measuring receiver's input (internally or externally) which provides adequate attenuation at the fundamental frequency to protect the input circuits of the receiver from overload and damage and to prevent the generation of harmonic and intermodulation signals.

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

NOTE 2 Several filters may be required to deal with more than one fundamental frequency.

Requirements for screening effectiveness, that is, the immunity to high ambient radiated disturbances, are under consideration.

6 Measuring receivers with average detector for the frequency range 9 kHz to 18 GHz

Average measuring receivers are generally not used for the measurement of impulsive disturbance. 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 to measure narrowband signals to overcome problems associated with either modulation content or the presence of broadband noise.

Spectrum analyzers that meet the requirements of this clause can be used for compliance measurements.

6.1 Input impedance

The input port of the measuring receiver 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 the values stated in Table 5.

Symmetric (balanced) input impedance in the frequency range 9 kHz to 150 kHz: use a balanced input transformer for symmetrical (that is, ungrounded) measurements. (The preferred input impedance for the frequency range 9 kHz to 150 kHz is 600 Ω.) Symmetric input impedance may be incorporated either in the relevant symmetrical artificial network required to couple to the receiver or, optionally, in the measuring receiver itself.

6.2 Fundamental characteristics

6.2.1 Bandwidth

The bandwidths shall lie within the values shown in Table 8.

Table 8 – Bandwidth requirements

Frequency range	Bandwidth B_6	Reference BW
9 kHz to 150 kHz (Band A)	100 Hz to 300 Hz [a]	200 Hz (B_6)
150 kHz to 30 MHz (Band B)	8 kHz to 10 kHz [a]	9 kHz (B_6)
30 MHz to 1 000 MHz (Bands C and D)	100 kHz to 500 kHz [a]	120 kHz (B_6)
1 GHz to 18 GHz (Band E)	300 kHz to 2 MHz [a]	1 MHz [b] (B_{imp})

[a] The subject of bandwidth is discussed in Clause E.1. If a bandwidth other than the reference BW is used, this bandwidth shall be stated when the disturbance level is reported.

[b] The bandwidth selected shall be defined as in Table 6.

6.2.2 Overload factor

For receivers with average detectors, 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, in general, it is not 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).

6.3 Sine-wave voltage accuracy

The accuracy of sine-wave voltage measurement shall be better than ±2 dB (± 2,5 dB above 1 GHz) when the receiver is fed with a sine-wave signal at 50 Ω resistive source impedance.

6.4 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 in the frequency range below 1 GHz.

6.4.1 Amplitude relationship

Up to 1 000 MHz, the average detector is defined as follows (linear average): the response of the measuring receiver to pulses of repetition rate *n* Hz and impulse area of 1,4/*n* mVs emf at 50 Ω source impedance, shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an emf with rms value of 2 mV [66 dB(μV)]. The source impedances of both the pulse generator and the signal generator shall be the same. The pulses shall have a uniform spectrum according to data shown in Table 2 of 4.4.1. 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 At repetition frequencies of 25, 100, 500, 1 000 and 5 000 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 9.

Table 9 – Relative pulse response of average and quasi-peak measuring receivers for the same bandwidth (frequency range 9 kHz to 1 GHz)

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 and D)				(38,1)	26,3
NOTE 1: The pulse response is based on the use of the reference bandwidth only (see Table 8).					
NOTE 2: Values in parentheses are for information only.					

Above 1 GHz (Band E), two modes of the average (weighting) detector are defined - linear and logarithmic:

For the linear average detector, the response of the measuring receiver to pulses of repetition rate *n* Hz and impulse area of 1,4/*n* mVs emf at 50 Ω source impedance shall be equal to the response of an unmodulated sine-wave signal at the tuned frequency having an emf of rms value of 2 mV [66 dB(μV)]. The pulse shall be defined as a pulse-modulated carrier. The value of n shall be 50 000. A tolerance of ±1,5 dB is permitted on the sine-wave voltage level.

For the logarithmic average detector, the response of the measuring receiver to pulses of repetition rate 333 kHz (inverse of period 3 μs) and impulse area of 6,7 nVs emf at 50 Ω source impedance shall be equal to the response of an unmodulated sine-wave signal at the tuned frequency having an c with rms value of 2 mV [66 dB(μV)]. A tolerance of ±4 dB is allowed on the sine-wave voltage level (the 10% tolerance of the bandwidth causes a possible variation of approximately ±2,5 dB).

For further details, see Clause E.6

NOTE 1 Average detection can be achieved with spectrum analyzers operated with a video bandwidth B_{video} << B_{resol} in order to achieve proper averaging based on the repetition frequency of the measured signal. For measurements based on a reduction of the video bandwidth, ensure the scanning time is sufficiently long to allow the video filter to respond correctly.

NOTE 2 For average (weighted) measurements in the linear mode, 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-wave signal taking alternatively the values 20 dB(µV) and 60 dB(µV), the level obtained in the logarithmic mode is 40 dB(µV), whereas in the linear mode, the level of 54,1 dB(µV) represents the true average value of the signal.

6.4.2 Variation with repetition frequency

The response to repetitive pulses of a measuring receiver equipped with a linear average detector 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 rule:

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

A tolerance of +3 dB to –1 dB is allowed in the frequency range from the lowest useable repetition frequency to a frequency equal to $B_3/2$, as determined from overload considerations.

NOTE The theoretical pulse response curves of quasi-peak and average detector receivers, combined on an absolute scale, are shown in Figure 1d. The response to repeated pulses of the measuring receiver equipped with a logarithmic average detector (above 1 GHz) is influenced by the noise level between the pulses. Using the following values:

L_{logAv} is the level indicated by the logarithmic average detector

T_P is the pulse duration

L_P is pulse level in dB(µV)

T_N is the duration of the noise level

L_N is noise level in dB(µV)

then the following approximate relationship applies:

$$L_{logAv} = \left(\frac{T_P L_P + T_N L_N}{T_P + T_N}\right)$$

Example: if the pulse level L_P is 85 dB(µV) and the noise level L_N is 8 dB(µV), T_P = $1/B_{imp}$ = 1 µs, the pulse rate n is 100 000, then $T_N \approx 9$ µs. From this equation, L_{logAv} = 15,7 dB(µV). In reality, L_{logAv} is higher because T_P is higher, because the pulse signal at the IF output does not drop to noise level immediately after 1 µs.

A tolerance is under consideration.

6.4.3 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 5. 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 4.

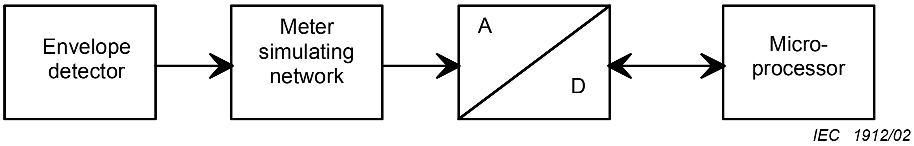


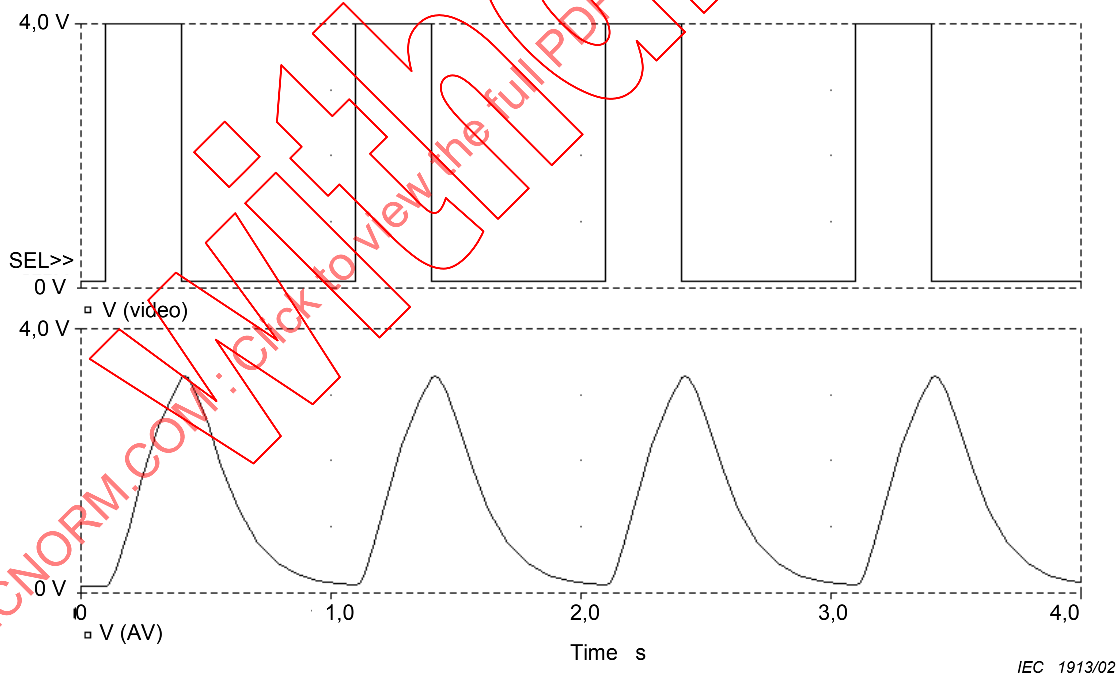
Figure 4 – Block diagram of an average detector.

For band E, the meter time constant for the linear average detector is 100 ms. For the logarithmic average detector, the requirement is under consideration.

It is deduced from the above requirement that an average measuring receiver shall yield the maximum reading listed in Table 10 for a radiofrequency sine-wave input signal modulated with repeated rectangular pulses having the duration and period indicated in the table. A tolerance of ±1,0 dB is allowed for this requirement.

Table 10 – 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)
NOTE In band E, this applies for the linear average detector only.		



NOTE The response to intermittent narrowband disturbances may be defined for the logarithmic average detector operating with a certain video bandwidth, for example, 10 Hz, and the maximum hold function of the spectrum display.

NOTE The response shown is caused by an intermittent narrowband signal with a duration of 0,3 s and a repetition frequency of 1 Hz, when a time constant of 100 ms is used. If the time constant is 160 ms, the peaks at the output of the meter simulating network will be lower.

Figure 5 – Response of the meter simulating network to an intermittent narrowband signal

6.5 Selectivity

For receivers with a bandwidth of 200 Hz (for the 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 the 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, Figures 2a, 2b and 2c describe the shape only and the frequency axis shall be scaled accordingly. The curve representing the overall selectivity of the measuring receiver reference bandwidth for band E shall lie within the limits of Figure 8.

The requirements of 4.5.2, 4.5.3 and 4.5.4 apply.

NOTE For the measurement of equipment that requires higher selectivity at the transition between 130 kHz and 150 kHz (for example, mains signalling equipment as defined in EN 50065-1[1]), 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.

6.6 Intermodulation effects, receiver noise, and screening

The requirements stated in 5.6 apply.

7 Measuring receivers with rms detector for the frequency range 9 kHz to 18 GHz

Spectrum analyzers that meet the requirements of this clause can be used for compliance measurements.

7.1 Input impedance

The input port of measuring receiver 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 the values stated in Table 5.

Symmetric (balanced) input impedance in the frequency range 9 kHz to 30 MHz: use a balanced input transformer for symmetrical (that is, ungrounded) measurements. (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 required to couple to the receiver or, optionally, in the measuring receiver itself.

[1] EN 50065-1:2001, *Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances*

7.2 Fundamental characteristics

7.2.1 Bandwidth

The bandwidth shall lie within the values shown in Table 11:

Table 11 – Bandwidth requirements

Frequency range	Bandwidth B_6	Reference BW
9 kHz to 150 kHz (Band A)	100 Hz to 300 Hz [a]	200 Hz (B_6)
150 kHz to 30 MHz (Band B)	8 kHz to 10 kHz [a]	9 kHz (B_6)
30 MHz to 1 000 MHz (Bands C and D)	100 kHz to 500 kHz [a]	120 kHz (B_6)
1 GHz to 18 GHz (Band E)	300 kHz to 2 MHz [a]	1 MHz [b] (B_{imp})

[a] The subject of bandwidth is discussed in Annex E, clause E.1. If a bandwidth other than the reference BW is used, the bandwidth shall be stated when the disturbance level is reported.

[b] The bandwidth selected shall be defined as in Table 6.

7.2.2 Overload factor

For receivers having rms detectors, 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, in general, it will not 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 should be determined.

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

7.3 Sine-wave voltage accuracy

The accuracy of sine-wave voltage measurement shall be better than ±2 dB (±2,5 dB above 1 GHz) when the receiver is fed with a sine-wave signal at 50 Ω resistive source impedance.

7.4 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 in the frequency range below 1 GHz.

7.4.1 Amplitude relationship

Up to 1 000 MHz, the rms detector is defined as follows: the response of the measuring receiver for Band A to pulses of impulse area $[278\ (B_3)^{-1/2}]$ µVs emf (with B_3 in Hz) 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 tuned frequencies, be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an emf with rms value of 2 mV [66 dB(µV)].

For the measuring receivers for Bands B, C and D, the corresponding values are $[139\ (B_3^{-1/2})]$ µVs (with B_3 in Hz) and 100 Hz. The source impedances of both the pulse generator and the signal generator shall be the same. A tolerance of ±1,5 dB is permitted in the sine-wave voltage levels prescribed above.

NOTE Annex A describes the calculation for the pulse response of the rms detector. At a repetition frequency of 25 Hz and 100 Hz, respectively, the relationship between the indications of an rms and a quasi-peak measuring receiver of the same bandwidth is given in Table 12.

Table 12 – Relative pulse response of rms and quasi-peak measuring receivers

Frequency range of measuring receiver	Pulse repetition range Hz	Ratio quasi-peak/rms 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
NOTE: The pulse response is based on the use of the reference bandwidth only (see Table 11).		

Above 1 GHz (Band E), the response of the measuring receiver to pulses of repetition rate 1 000 Hz and impulse area emf at 50 Ω source impedance equal to $[44\ (B_3)^{-1/2}]$ μVs, shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an emf with rms value of 2 mV [66 dB(μV)]. The pulse shall be defined as a pulse-modulated carrier. For further details, see Clause E.6.

7.4.2 Variation with repetition frequency

The response of a measuring receiver equipped with rms detector 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 rule:

Amplitude proportional to (repetition frequency)–1/2

The response curve for a particular receiver shall lie between the limits in Table 13.

Table 13 – Pulse response of rms measuring receiver

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

7.5 Selectivity

Because the bandwidth requirements stated in 7.2.1 allow variations from the bandwidths given in Figures 2a, 2b and 2c, these selectivity curves apply to rms measuring receivers in regards to shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in Figure 2a. The curve representing the overall selectivity of the measuring receiver reference bandwidth for band E shall lie within the limits of Figure 8.

The requirements stated in 4.5.2, 4.5.3 and 4.5.4 apply.

7.6 Intermodulation effects, receiver noise, and screening

The requirements stated in 5.6 apply.

8 Measuring receivers for the frequency range 1 GHz to 18 GHz with amplitude probability distribution (APD) measuring function

APD of disturbance is defined as the cumulative distribution of the “probability of time that the amplitude of disturbance exceeds a specified level”.

APD can be measured at the output of the envelope detector or the succeeding circuits of an RF measuring receiver or a spectrum analyzer. The amplitude of disturbance should be expressed in terms of the corresponding field strength or voltage at the receiver input. Usually, an APD measurement is carried out at a fixed frequency.

The APD measuring function will be an additional function of the measuring apparatus and may be attached to, or incorporated in the measuring instrument.

The APD measuring function can be implemented using the following methods. One approach uses comparators and counters (Figure G.1). The equipment determines the probabilities of exceeding a set of pre-assigned amplitude (i.e. voltage) levels. The number of levels equals the number of comparators. Another possible method involves the use of an analog-to-digital converter, a logic circuit, and memory (Figure G.2). The equipment can also provide the APD figure for a set of pre-assigned amplitude levels. The number of levels depends on the resolution of the analog-to-digital converter (e.g. 256 levels for an 8-bit converter).

APD measurements using the aforementioned function are applicable to products or product families if their potential to cause interference to digital communication systems is to be determined (see CISPR 16-3, Amendment 1, subclause 4.7, for background material to amplitude probability distribution (APD) specifications).

The following specifications apply to the APD measuring function. A rationale for these specifications is provided in Annex G.

- **Specifications**

a) The dynamic range of the amplitude shall be greater than 60 dB.

b) The amplitude accuracy, including threshold level setting error, shall be better than ±2,7 dB.

c) The maximum measurable time of a disturbance shall be longer than or equal to 2 min. The intermittent measurement can be used if the dead time is less than 1 % of the total measurement time.

d) The minimum measurable probability shall be 10^{-7}.

e) The APD measuring function shall be capable of assigning at least two amplitude levels. The probabilities corresponding to all pre-assigned levels shall be measured simultaneously. The resolution of the pre-assigned amplitude levels shall be 0,25 dB at a minimum or better

f) The sampling rate shall be greater than or equal to 10 million samples per second when using a resolution bandwidth of 1 MHz.

- **Recommended specification**

g) amplitude resolution of the APD display should be less than 0,25 dB for APD measuring equipment with an A/D converter.

NOTE APD measurements may also be applicable in the frequency range below 1 GHz.

9 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 14-1:2005.

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.

9.1 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 ±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 6.

f) For validation of the fundamental characteristics the analyzer has to pass the performance check with all the wave forms (test pulses) in Table 14.

   Figure 7 presents in a graphical form the waveforms listed in Table 14.

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

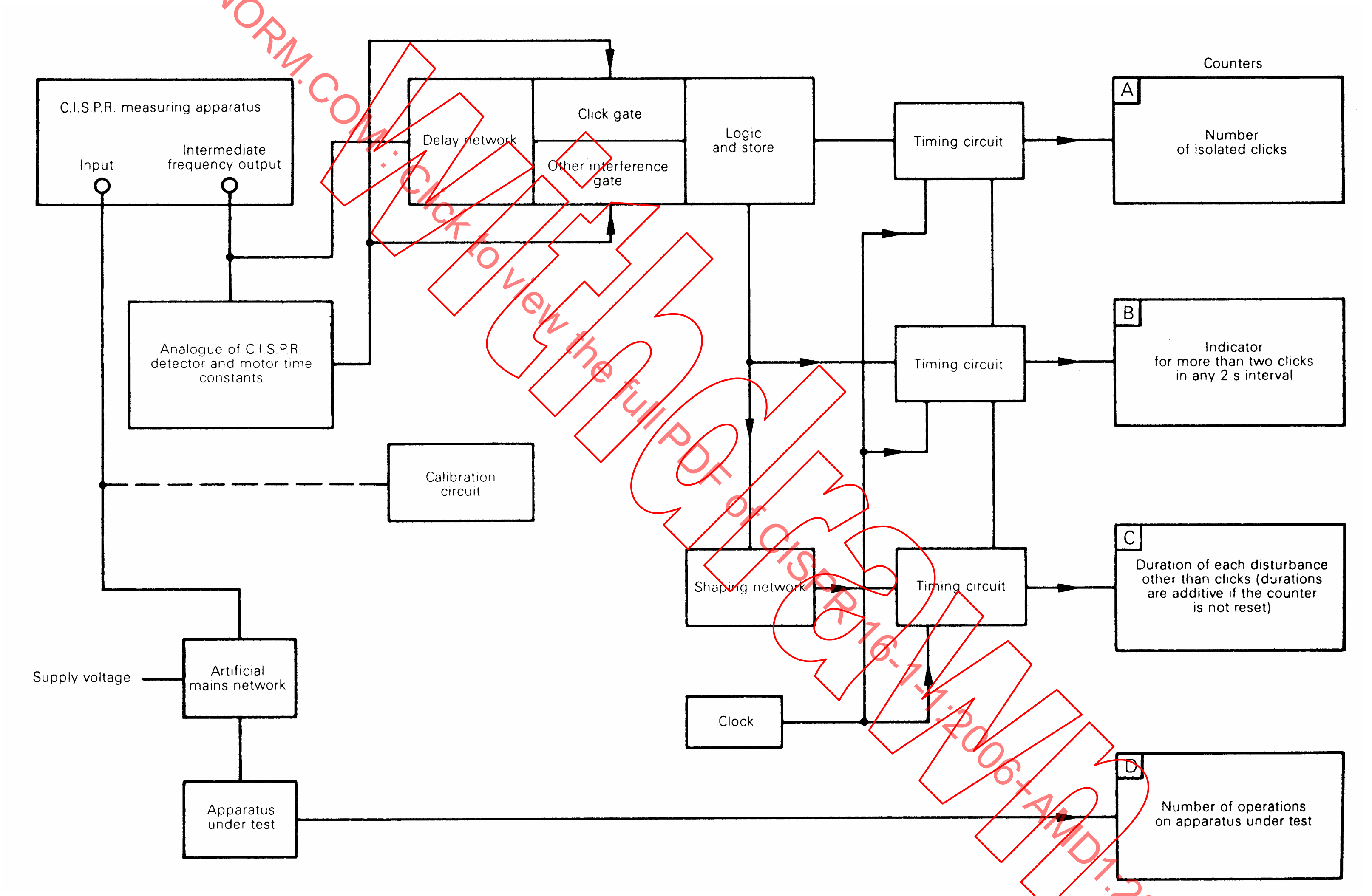


Figure 6 – Example of a disturbance analyzer

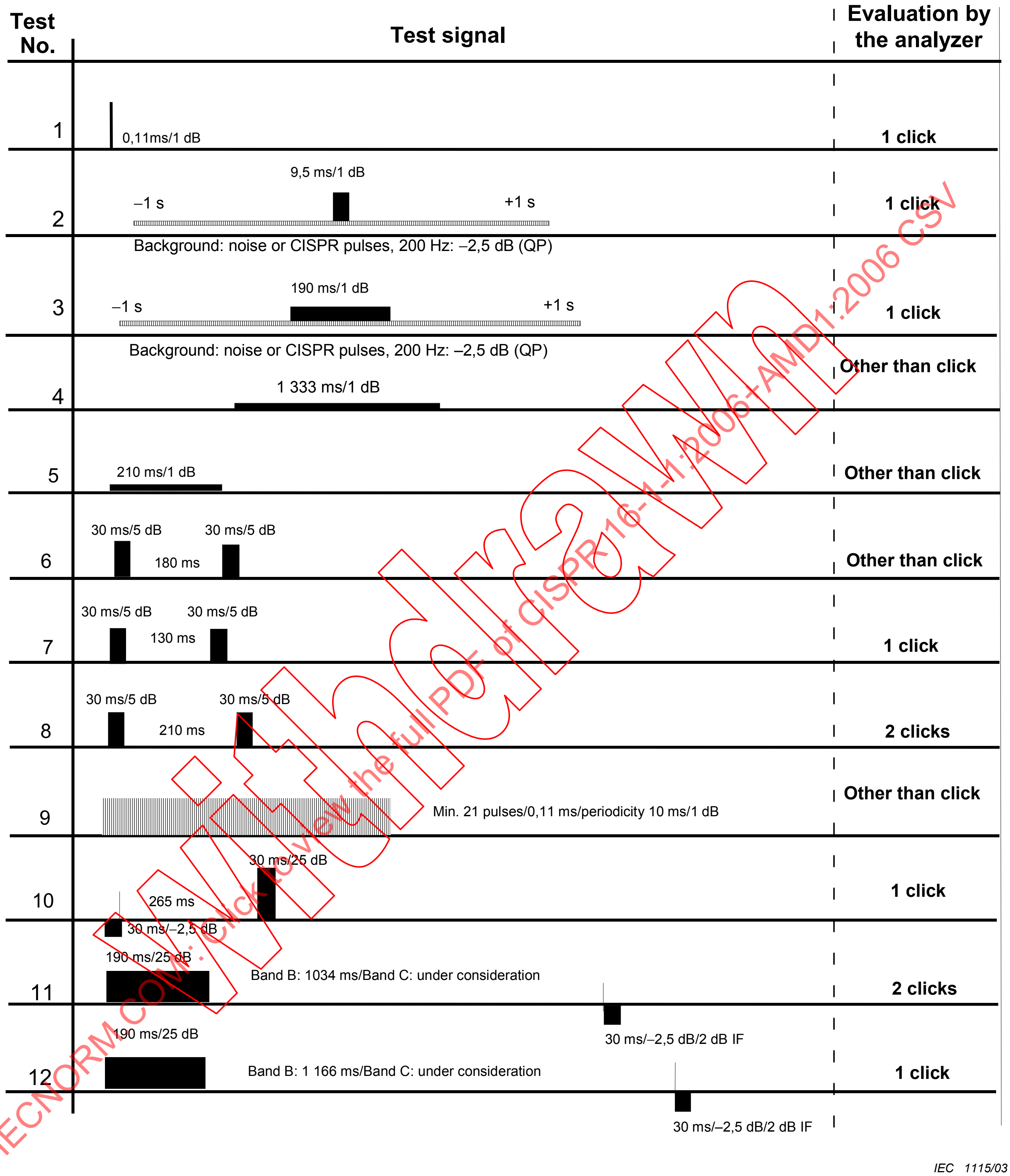


Figure 7 – A graphical presentation of test signals used in the test of the analyzer for the performance check against the definition of a click according to Table 14

**Table 14 – Disturbance analyzer performance test –
Test signals used for the check against the definition of a click**

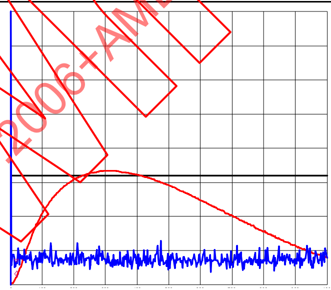
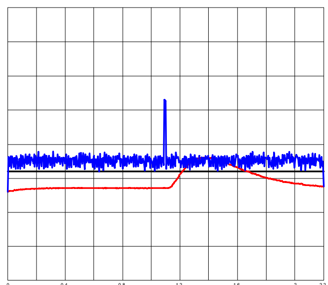
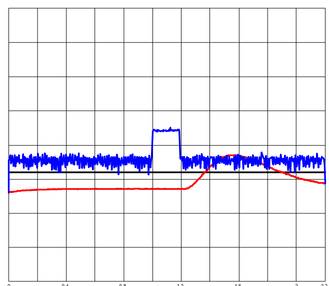
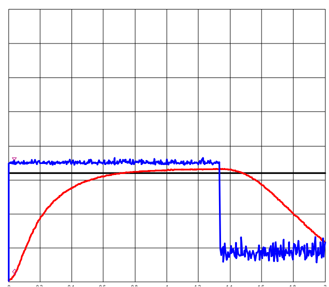
Test No.	Test signal parameters						
	1		2		3	4	5
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses [f] adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (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			
1	1		0,11			1 click	 1 s
2 [a]	1		9,5			1 click	 2,2 s
3 [a]	1		190			1 click	 2,2 s
4	1		1 333 [b]			Other than click	 2 s

Table 14 (*continued*)

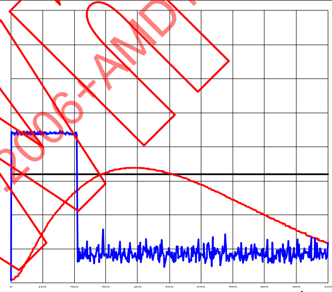
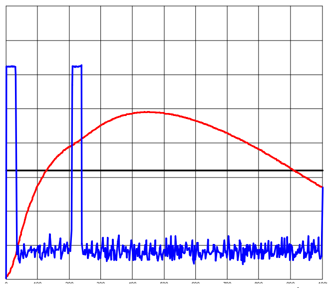
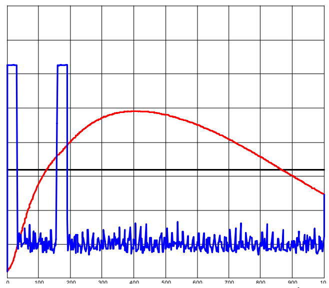
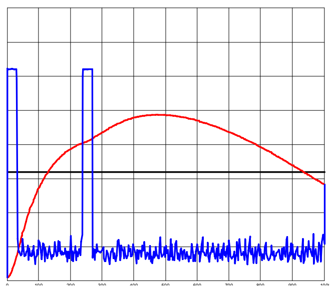
Test No.	Test signal parameters						
	1		2		3	4	5
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses [f] adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (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 14 (*continued*)

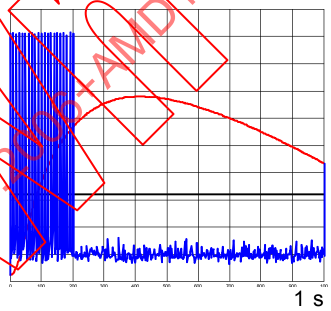
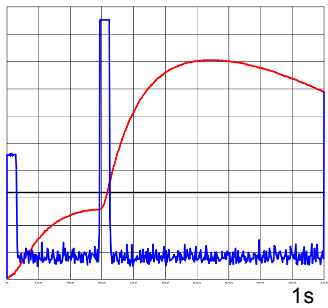
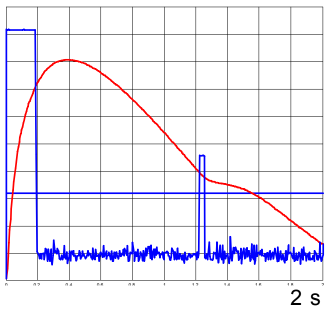
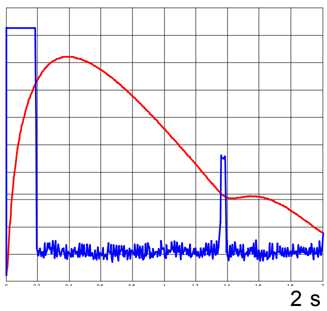
Test No.	Test signal parameters						
	1		2		3	4	5
	QP amplitude of impulses adjusted individually relative to QP reference indication of the measurement receiver dB		Duration of impulses [f] adjusted in the intermediate frequency output of the measurement receiver ms		Separation of impulses or periodicity (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			
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 14 (*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.

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

9.2.1 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 be not longer than 40 µs. The pulse duration shall be variable between 110 µs 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 14. The amplitudes of the pulses shown in column 1 of Table 14 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.

9.2.2 Additional requirements

The test method is identical to the one described in 9.2.1a).

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

Annex A
(normative)

Determination of response to repeated pulses of quasi-peak and r.m.s. measuring receivers
(subclauses 3.2, 4.4.2, 7.2.2 and 7.4.1)

A.1 General

This annex sets out the data for the numerical calculation, and the procedure for establishing the curve of response to repeated pulses. The assumptions inherent in the method are also stated. The calculation is divided into three successive stages.

A.2 Response of the pre-detector stages

The pulse response of these stages is, in general, determined solely by the IF stages that define the overall selectivity of the receiver.

It is common practice to consider that this selectivity can be obtained by an assembly of two critically-coupled tuned transformers arranged in cascade so as to produce the desired pass-band at the –6 dB points. Any other equivalent arrangement can be reduced to the above for purposes of calculation. The practical symmetry of this pass-band permits the use of the equivalent low-pass filter for calculating the envelope of the pulse response. The error resulting from this approximation is negligible.

The envelope of the pulse response is written:

$$A(t) = 4\ \omega_0 G e^{-\omega_0 t} (\sin \omega_0 t - \omega_0 t \cos \omega_0 t) \qquad \text{(A.1a)}$$

where

G is the overall gain at tuned frequency;

ω_0 is the angular frequency of value $(\pi/\sqrt{2})\ B_6$.

The envelope of the response of two critically-coupled tuned transformers to an impulse area $\upsilon\tau$ is, from the previous equation:

$$A(t) = (\upsilon\tau)\ 4\ \omega_0 G e^{-\omega_0 t} (\sin \omega_0 t - \omega_0 t \cos \omega_0 t) \qquad \text{(A.1b)}$$

The corresponding selectivity curve of the equivalent low-pass filter may be written, for $\tau << 1/\omega_0$:

$$F(f) = G\left[\left(2\omega_0^{\ 2}\right)/\left((\omega_0 + j\omega)^2 + \omega_0^{\ 2}\right)\right]^2 \qquad \text{(A.2)}$$

where

$\omega = 2\pi f$.

The bandwidths B_3 and B_6 will be:

$$B_3 = \left[\sqrt{2} \times \sqrt[4]{(\sqrt{2} - 1)}\right]\ \omega_0/\pi = 0{,}361\ \omega_0 \qquad \text{(A.3a)}$$

$$B_6 = \sqrt{2} \times \omega_0/\pi = 0{,}450\ \omega_0 \qquad \text{(A.3b)}$$

The effective bandwidth of a receiver, comprising an idealized rectangular filter giving the same r.m.s. value of response as an actual receiver, is equal to the power bandwidth Δf defined as:

$$\Delta f = (1/F_0^2) \int_{-\infty}^{+\infty} F^2(f)\, \mathrm{d}f \qquad \text{(A.4)}$$

where

$F(f)$ is the selectivity curve;

F_0 is the maximum value of $F(f)$ (assuming a single peak selectivity curve).

The power bandwidth is then, for $F_0 = 1$

$$\Delta f = \int_{-\infty}^{+\infty} F^2(f)\, \mathrm{d}f \qquad \text{(A.5)}$$

Taking $F(f)$ from equation (A.2) and putting $G = 1$, we have:

$$\Delta f = \int_0^{\infty} 2\left[\left(2\omega_0^2\right)/\left(\left(\omega_0 + j\omega\right)^2 + \omega_0^2\right)\right]^4 df \qquad \text{(A.6)}$$

this leads to:

$$\Delta f = 0{,}265\ \sqrt{2} \times \omega_0 = 0{,}375\ \omega_0 \qquad \text{(A.7)}$$

thus:

$$B_3 = 0{,}963\ \Delta f \qquad \text{(A.8)}$$

A.3 Response of the quasi-peak voltmeter detector to output of preceding stages

The calculation is made on the assumption that the connection of the detector circuits to the output of the last IF stages does not affect either the amplitude or the shape of the signal therefrom. In other words, the output impedance of this stage is regarded as negligible compared with the input impedance of the detector.

Any detector may be reduced to the form (actual or equivalent) of a non-linear element (for example a diode) in association with a resistance (total forward resistance S) and followed by a circuit consisting of a capacitance C in shunt with a discharge resistance R.

The electrical charge time constant T_C is related to the product SC, while the electrical discharge time constant T_D is given by the product RC.

The relationship between T_C and the product SC will be established by obtaining, in a time $t = T_C$, an indicated voltage of 0,63 times the final steady value when a constant amplitude RF signal is suddenly applied.

The voltage U across the capacitor is related to the amplitude A of the RF signal applied to the detector by the equation:

$$dU/dt + U/(RC) = A\,(\sin\theta - \theta\cos\theta)/(\pi \times SC) \qquad (A.9)$$

where θ is the conduction angle ($U = A\cos\theta$).

This equation is not directly integrable. A value for the product SC, which, for the time constants chosen satisfies the above conditions, is found by methods of approximation, for example:

in band A:	T_C	=	45 ms
	T_D	=	500 ms
	2,81SC	=	1 ms
in band B:	T_C	=	1 ms
	T_D	=	160 ms
	3,95SC	=	1 ms
in bands C and D:	T_C	=	1 ms
	T_D	=	550 ms
	4,07SC	=	1 ms

By inserting the value thus obtained in equation (A.9), this may be solved for either an isolated pulse or repeated pulses (again by methods of approximation) by introducing, in place of the constant amplitude A, the function $A(t)$ given by equation (A.1) in clause A.2.

This case of repeated pulses can be solved practically only by arbitrarily assuming a level for the output voltage of the detector at the start of each pulse, by determining the increment ΔU of this voltage caused by the pulse, and then finding the spacing which must exist between two successive pulses in order to repeat the assumed initial conditions.

A.3.1 Response of the indicating instrument to the signal from the detector

The only simplifying, but perfectly legitimate, assumption is that the rising portion of the output voltage of the detector is instantaneous.

The following characteristic equation then has to be solved:

$$\frac{d^2\alpha}{dt^2} + \frac{2}{T_M}\frac{d\alpha}{dt} + \frac{1}{T_M^2}\alpha = \frac{1}{T_M^2}\exp\left(\frac{-t}{T_D}\right) \qquad (A.10)$$

where

$\alpha(t)$ is the instrument deflection;

T_D is the electrical discharge time constant of the quasi-peak voltmeter;

T_M is the mechanical time constant of the critically damped indicating instrument.

The solution of the problem is relatively simple for the two extremes of the response curve; on the one hand, for pulses sufficiently separated for the starting point to be zero and thus known, and on the other, for pulses having a sufficiently high repetition rate for the inertia of the instrument to prevent it following the fluctuations faithfully. For the intermediate cases, the calculation becomes more complicated. At the start of each pulse, the instrument deflection is varying and it is necessary to find a solution which takes account of the initial position and velocity.

A.4 Response of r.m.s. detector to output voltage of preceding stages

By definition, the output voltage of the r.m.s. detector is given by:

$$U_{rms} = \left[n \int_{0}^{+\infty} (A^2(t)/2)\mathrm{d}t \right]^{1/2} \quad \text{(A.11)}$$

where

n is the pulse repetition frequency in hertz.

The output may also be deduced from the frequency response curve as:

$$U_{rms} = \left[n \int_{-\infty}^{+\infty} (2\upsilon\tau \times F^2(f)/2)\mathrm{d}f \right]^{1/2} \quad \text{(A.12)}$$

where

$\upsilon\tau$ is the area of pulse having a uniform frequency spectrum.

This gives:

$$U_{rms} = \sqrt{2} \times \upsilon\tau \times \sqrt{n} \left[\int_{-\infty}^{+\infty} F^2(f)\mathrm{d}f \right]^{1/2} \quad \text{(A.13)}$$

Which, from equation (A.5), gives:

$$U_{rms} = \sqrt{2} \times \upsilon\tau \times \sqrt{n}\ \sqrt{\Delta f} \quad \text{(A.14)}$$

From equation (A.14), the amplitude relationship may be deduced by taking:

U_{rms} = 2 mV, when n = 100 Hz

thus:

$$\upsilon\tau = (100\ \sqrt{2}\ ) / \sqrt{\Delta f} \quad (\mu\text{Vs}) \quad \text{(A.15)}$$

or from equation (A.8):

$$\upsilon\tau = 139 / \sqrt{B_3} \quad (\mu\text{Vs}) \quad \text{(A.16)}$$

A.4.1 Calculation of overload factor

The overload factor corresponding to a pulse repetition frequency of n Hz is calculated as follows:

From equation (A.14):

$$U_{rms} = (\upsilon\tau) \times (2n\ \Delta f)^{½}$$

from equation (A.1), and for G = 1:

$$A(t)_{peak} = 0{,}944 \times \upsilon\tau \times \omega_0$$

thus overload factor:

$$A(t)_{peak} / \sqrt{2} \times U_{rms} = 1{,}28\ (B_3/n)^{½} \quad \text{(A.17)}$$

A.5 Relationship between indication of r.m.s. meter and quasi-peak meter

The amplitude relationship for the r.m.s. meter which states the value of pulse $(\upsilon\tau)_{rms}$ for the case of 100 Hz, which is equivalent to a sine-wave signal of 2 mV is, from equation (A.16):

$$(\upsilon\tau)_{rms} = 139 / \sqrt{B_3} \quad (\mu Vs)$$

For the selectivity characteristic quoted in equation (A.2), this corresponds to:

$$(\upsilon\tau)_{rms} = 155 / \sqrt{B_6} \quad (\mu Vs)$$

when reference is made to the bandwidth at 6 dB.

For the quasi-peak receiver, the value of pulse $(\upsilon\tau)_{qp}$ which is equivalent to a sine-wave signal of 2 mV is as follows:

for the frequency range 0,15 MHz to 30 MHz:

$$(\upsilon\tau)_{qp} = 0{,}316\ \mu Vs$$

for the frequency range 30 MHz to 1 000 MHz:

$$(\upsilon\tau)_{qp} = 0{,}044\ \mu Vs$$

Thus for measuring receivers having band-pass characteristics according to equation (A.2) and a bandwidth at 6 dB equal to the nominal bandwidths prescribed in clauses 4, 5, 6 and 7 the following relationships for $(\upsilon\tau)_{rms}/(\upsilon\tau)_{qp}$ exist:

for the frequency range 0,15 MHz to 30 MHz:

$$(\upsilon\tau)_{rms}/(\upsilon\tau)_{qp} = 14{,}3\ dB$$

for the frequency range 30 MHz to 1 000 MHz:

$$(\upsilon\tau)_{rms}/(\upsilon\tau)_{qp} = 20{,}1\ dB$$

These relationships are valid for a pulse repetition frequency of 100 Hz. At other repetition frequencies, it is necessary to use the corresponding pulse response curves.

Annex B
(normative)

Determination of pulse generator spectrum
(subclauses 4.4, 5.4, 6.4, 7.4)

B.1 Pulse generator

For checking compliance with the requirements of this standard, a pulse generator is needed. Compliance with the requirements of 4.4, 4.6, 5.4, 6.4 and 7.4 may be tested using the pulse generator technique.

For each frequency band of the measuring receiver under test, the generator used shall be capable of producing pulses with the impulse area specified and over the range of repetition frequencies given in Table B.1. The impulse area should be known within ±0,5 dB and the repetition frequency to within about 1 %.

Table B.1 – Pulse generator characteristics

Frequency band of receiver under test	Impulse area µVs	Repetition frequency Hz
0,09 to 0,15 MHz	13,5	1, 2, 5, 10, 25, 60, 100
0,15 to 30 MHz	0,316	1, 2, 10, 20, 100, 1 000
30 to 300 MHz	0,044	1, 2, 10, 20, 100, 1 000
300 to 1 000 MHz	(see note)	1, 2, 10, 20, 100, 1 000
NOTE The generator should be capable of producing pulses of adequate impulse area with as uniform a spectrum up to 1 000 MHz as possible.		

B.1.1 The spectrum of the generated pulses

The spectrum is defined by a curve that represents as a function of the tuned frequency of the receiver under test, the law of variation of the equivalent voltage at the input of a measuring apparatus having a constant bandwidth.

The spectrum should be substantially constant up to the upper limit of the frequency band of the receiver under test. The spectrum may be regarded as satisfactorily uniform if, within this band, the variation of the spectrum amplitude is not greater than 2 dB relative to its value for the lower frequencies within the band. The impulse area at the measurement frequency shall be known to within ±0,5 dB.

For checking compliance with the requirements of 4.6, the spectrum above the upper limit of the frequency band shall be limited (10 dB down at twice the upper frequency). This is necessary to standardize the severity of the test since the inter-modulation products of all components of the spectrum will contribute to the response.

B.2 General method of measurement

Methods for the accurate determination of the absolute value of the spectrum amplitude of pulses are given in Annex C.

For measurement of the variation of the spectrum amplitude with frequency, the following method may be used.

The pulse generator is connected to the input of an RF receiver followed by an oscilloscope connected so as to indicate the RF pulse at the output of the receiver.

At each frequency of tuning of the receiver, the following are measured:

a) the bandwidth, B_6 Hz, of the receiver at the –6 dB points,
b) the r.m.s. value, E_0, of the output from a standard signal generator having the same impedance as the pulse generator and tuned to the mid-band of the receiver and producing on the oscilloscope a deflection equal in amplitude to the peak of the RF pulses.

The relative spectrum amplitude at each frequency is taken to be:

$$S_\tau(f) = E_0/B_6$$

The measurement is repeated for various test frequencies in the band under consideration.

The spectrum of the pulse generator is given by the curve relating $S_\tau(f)$ to the measurement frequency.

The receiver used should be linear for the peak levels of the signals used.

The suppression of parasitic responses, in particular the image frequency and IF responses, should be at least 40 dB.

The measurements may be made with a receiver conforming to the present specification, using the quasi-peak indicator in place of the oscilloscope, provided that the repetition frequency of the pulses is kept constant throughout the series of measurements.

Annex C
(normative)

Accurate measurements of the output of nanosecond pulse generators
(subclauses 4.4, 5.4, 6.4, 7.4)

C.1 Measurement of impulse area (IS)

C.1.1 General

Theoretical and practical investigations have shown that, when applied with reasonable care, accurate methods of measurement include those given in C.1.2 to C.1.5.

C.1.2 Area method

The pulses to be measured are fed through a narrow band filter whose passband is centred at frequency *f* having a symmetrical amplitude characteristic, and an asymmetrical phase characteristic (in conjunction with a filter, an amplifier may be used provided it is operated in its linear range).

The total area under the envelope $A(t,f)$ of the output from the band-pass filter (taking into account the sign of different parts of it) is measured, so as to evaluate the integral in the equation.

$$2(IS) = S(f) = \int_{-\infty}^{+\infty} A\,(t,f)\,\mathrm{d}t$$

where S(f) is the spectral intensity and $A(t,f)$ is the magnitude of the envelope due to a single isolated pulse (expressed in terms of equivalent input sine-wave voltage).

In applying this equation, the intermediate-frequency amplifier of a low-frequency receiver or a disturbance measuring receiver is used together with a series of frequency converters to tune across the spectrum of the pulse. The output of the final intermediate-frequency amplifier is taken directly to an oscilloscope for the area measurement.

In a variation of this method for pulses of duration much shorter than the period of the frequency (f), the impulse area can be measured directly as an integrated area by means of a suitable oscilloscope (for example, for nanosecond pulses, a sampling oscilloscope is required), the integration taking into account the sign of different parts of the area.

C.1.3 Standard transmission line method

A transmission line of length corresponding to a propagation time τ and charged to a voltage V_0 is discharged into a load resistance equal to the characteristic impedance of the line. The transmission line is considered to consist of the actual line as well as the charged section of the line contained in the switch housing. It has been found that spectral intensity, $S(f)$, has the value $2\upsilon\tau$ in the low-frequency portion of the spectrum of the resulting pulse in which the amplitude is constant with frequency, this amplitude being independent of the existence of certain stray impedances between the line and the load resistor (e.g. inductance or resistance) or of finite switching time.

C.1.4 Harmonic measurement

This method may be used for pulse generators producing a sequence of pulses with sufficiently high and stable repetition frequency.

When the pulse repetition frequency F exceeds the values of the bandwidth of the measuring receiver, the latter may select one line from the pulse spectrum. In this case, the impulse area may be determined as follows:

$$IS = V_K/2F = V\sqrt{2}/2F$$

where $V_K = V\sqrt{2}$ is the peak value of the k-th harmonic.

The pulse generator may then be used to calibrate the pulse response characteristics of a measuring receiver in which the bandwidth is sufficiently wide to accept many harmonic components (approximately 10 or more within the 6 dB bandwidth).

C.1.5 Energy method

Another method compares the power produced by a thermal source (resistor) with that produced by the pulse generator. However, the accuracy obtained with this method is somewhat less than with the three methods mentioned above. This method may be useful at frequencies of the order of 1 000 MHz.

C.2 Pulse generator spectrum

C.2.1 To determine compliance with 4.4.1, 5.4, 6.4.1 and 7.4.1, the impulse area shall be known with an error not greater than ±0,5 dB.

C.2.2 The pulse repetition frequency shall be known with an error not greater than 1 %.

C.2.3 For determining compliance with 4.4.2, 5.4, 6.4.2 and 7.4.2 the impulse area shall not depend on their repetition frequency.

C.2.4 For determining compliance with 4.4, 5.4, 6.4 and 7.4 the generator frequency spectrum should be uniform over the pass-band of the measuring receiver. This requirement is considered to be fulfilled in the following cases:

a) if variation of the frequency spectrum is substantially linear with respect to frequency within the frequency passband of the receiver, and the spectrum irregularity does not exceed 0,5 dB within the receiver passband measured at the –6 dB points;

b) if the frequency spectrum is smoothly tapered on both sides from the tuning frequency of the receiver, and if the spectrum width at the –6 dB points is at least five times greater than the receiver passband at that level.

In both cases, the impulse area is assumed to be equal to its value at the tuning frequency.

Annex D
(normative)

Influence of the quasi-peak measuring receiver characteristics on its pulse response
(subclause 4.4.2)

The level of the pulse response curve for high repetition frequencies depends essentially on the magnitude of the bandwidth. On the other hand, for low repetition frequencies, the time constants play the more important role. No tolerance has been stated for these time constants, but it is suggested for guidance that a value of 20 % is considered reasonable.

It is also at very low repetition frequencies that the effect of lack of overload factors will be most noticeable. The values required for the overload factors are those necessary for the accurate measurement of an isolated pulse using the bandwidth and the time constants prescribed.

Examination of the pulse response-curve at the two ends of the range of the indicating instrument provides a check on possible non-linear behaviour of the detector. The most critical repetition frequencies in this respect will most probably be in the neighbourhood of 20 Hz to 100 Hz.

Annex E
(normative)

Response of average and peak measuring receivers
(subclause 6.2.1)

E.1 Response of pre-detector stages

It has been shown* that the area under the envelope of the impulse response curve of a narrowband circuit having a symmetrical frequency characteristic is independent of the bandwidth, and is given by:

$$\int_{-\infty}^{+\infty} A(t)dt = 2\nu\tau G_0 \tag{E.1}$$

where υ and τ are the amplitude and duration of a rectangular pulse for which $B_{imp}\ \tau << 1$ and G_0 is the gain of the circuit at the centre frequency.

This theorem is valid only in the case of a non-oscillating envelope. The oscillatory envelope is characteristic of double-tuned circuits, and unless a phase sensitive detector is used, it may be necessary to compensate by calibration the error introduced by the oscillatory response. In the case of critical coupling, the second peak of the envelope is about 8,3 % of the first one.

NOTE The response of the pre-detector stages as defined in clause A.2 is oscillatory. Therefore, the calibration error introduced by the oscillatory response shall be compensated with a biased tolerance of +2,5 dB/–0,5 dB in 6.4.1.

As long as pulses do not overlap in the output of the IF amplifier, the average value is proportional to the pulse repetition rate, n.

Therefore, the average voltage is equal to $2\upsilon\tau G_0 n$.

In view of equation (E.1), it is not considered meaningful to define an effective bandwidth for an average measuring receiver.

E.2 Overload factor

For calculation of overload factor and for use in connection with peak measuring receivers, it is useful to define a quantity known as the effective impulse bandwidth of the pre-detector circuit as follows:

$$B_{imp} = A(t)_{max} / 2G_0 \tag{E.2}$$

where

$A(t)_{max}$ is the peak envelope output of the intermediate-frequency stages with a unit impulse applied.

* *"Response of ideal radio noise meter to continuous sine-wave, recurrent impulses, and random noise"* by David B. Geselowitz, IRE Transactions, RFI, Vol. RFI-3, no. 1, pp 2-11, May, 1961. See also, *"Impulse excitation of a cascade of series tuned circuits"* by S. Sabaroff, Proc. IRE, Vol. 32, pp 758-760, December 1944.

From the work leading to equation (A.17) (Annex A), we have:

$$B_{imp} = (0{,}944/2)\ \omega_0 = 1{,}05\ B_6 \text{ or } 1{,}31\ B_3 \qquad \text{(E.3)}$$

where B_6 and B_3 are defined in 3.2.

For other types of tuned circuits, the ratio of B_{imp} to B_6 may be estimated from Figure E.1 if the ratio of B_{20} to B_3 is known, where B_{20} is the bandwidth at 20 dB.

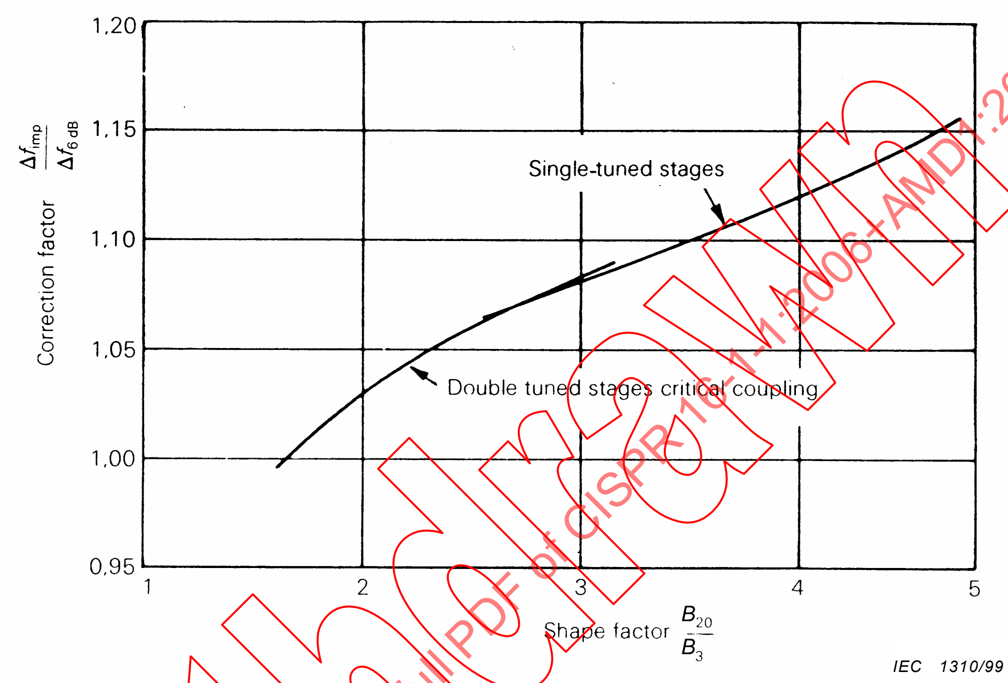


Figure E.1 – Correction factor for estimating the ratio B_{imp}/B_6 for other tuned circuits

E.3 Relationship between indication of an average and a quasi-peak measuring receiver

At a repetition rate of *n* Hz, the value of impulse area required to produce a response on an average measuring receiver equivalent to the response to an unmodulated sine-wave signal at the tuned frequency of r.m.s. value 2 mV from a signal generator having the same output impedance as the pulse generator is:

$$\upsilon\tau = 1{,}4/n \text{ (mVs)}$$

At a repetition rate of 100 Hz, this is 14 µVs.

Therefore, from clause A.5 of Annex A, the ratio of $(\upsilon\tau)_{ave}$ to $(\upsilon\tau)_{qp}$ to produce the same indication will be:

for the frequency range 0,15 MHz to 30 MHz:

$$(\upsilon\tau)_{ave}/(\upsilon\tau)_{qp} = 32{,}9 \text{ dB}$$

for the frequency range 30 MHz to 1 000 MHz:

$$(\upsilon\tau)_{ave}/(\upsilon\tau)_{qp} = 50{,}1 \text{ dB}$$

The above assumes adequate overload factor at the repetition rate in question, and that the bandwidths in use correspond respectively to those in clause 4. At a repetition rate of 1 000 Hz, the corresponding ratios will be 17,4 dB and 38,1 dB.

E.4 Peak measuring receivers

Where a direct-reading meter is used in the receiver, the requirement for time constants can be determined from the curve in Figure E.2, which shows the percentage of the reading referred to the true peak in function of a parameter and which includes the time constants ratio, the bandwidth B_6 and the pulse repetition rate. In using this curve, it should be noted that:

$$R_C/R_D = (1/4)\ (T_C/T_D) \qquad \text{(E.4)}$$

where T_C and T_D are respectively the charge and discharge time constants.

For example, if it is desired to have the receiver read at least 90 % of true peak at a repetition rate of 1 Hz, it would be necessary to have a discharge-time constant to charge time constant ratio of:

$1{,}25 \times 10^6$ in the frequency range 0,15 MHz to 30 MHz;

$1{,}67 \times 10^7$ in the frequency range 30 MHz to 1 000 MHz.

E.5 Relationship between indication of a peak and a quasi-peak measuring receiver

The value of impulse area, *IS*, required to produce a response on a peak measuring receiver equivalent to the response to an unmodulated sine-wave signal at the tuned frequency of r.m.s. value 2 mV is:

$$1{,}4/B_{imp}\ \text{(mVs)}\ (B_{imp} \text{ in Hz}) \qquad \text{(E.5)}$$

From the 6 dB bandwidths specified in Table 1 (4.2), the B_{imp} values are obtained as $1{,}05B_6$ (clause E.2). These values and the corresponding *IS* values required for a peak meter will be:

Frequency	*IS peak (mVs)*	B_{imp} *(Hz)*
Band A	$6{,}67 \times 10^{-3}$	$0{,}21 \times 10^3$
Band B	$0{,}148 \times 10^{-3}$	$9{,}45 \times 10^3$
Bands C and D	$0{,}011 \times 10^{-3}$	126×10^3

Therefore, using the values given as a) in Table 2 (in 4.4.1) for *IS* quasi-peak, the ratio of *IS* quasi-peak to *IS* peak to produce the same indication will be:

For Band A 6,1 dB (at 25 Hz pulse repetition frequency)

For Band B 6,6 dB (at 100 Hz pulse repetition frequency)

For Bands C and D 12,0 dB (at 1 000 Hz pulse repetition frequency)

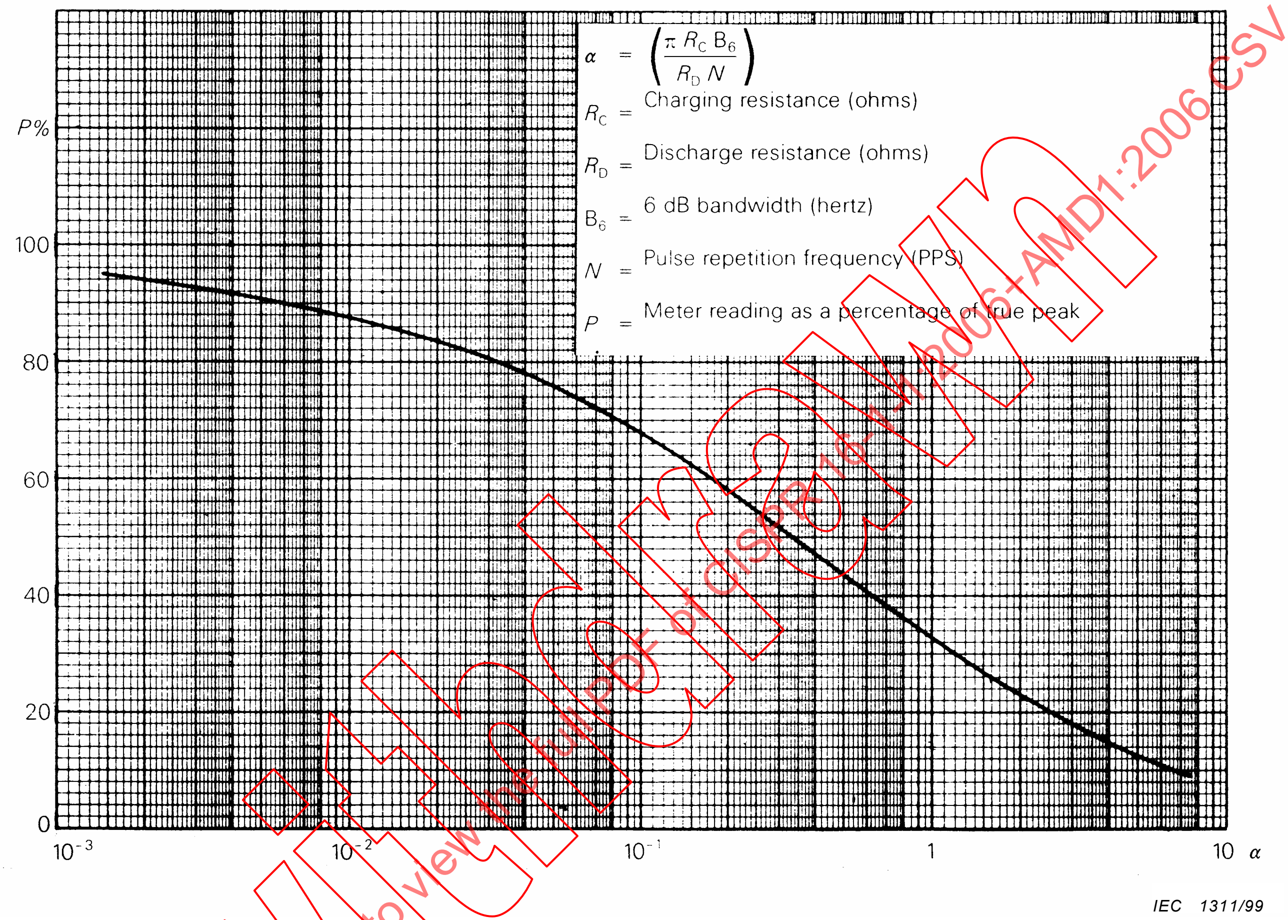


Figure E.2 – Pulse rectification coefficient *P*

E.6 Test of measuring receiver response above 1 GHz to pulses

Pulse generators with a uniform spectrum up to 18 GHz are not feasible. To test the response of measuring receivers above 1 GHz to pulses and to verify the amplitude relationship of various types of measuring receivers, it is practical to use a pulse-modulated carrier tuned to the receive frequency. The pulse width shall be less than or equal to (1/3 B_{imp}). The accuracy of the impulse width is important for the precise generation of a certain impulse area as required in the relevant subclause. In addition to a measurement of the pulse duration using an oscilloscope, the pulse duration of a rectangular pulse can be verified by the distance between the minima on the spectrum display. (See Figure E.3 for a sample waveform.)

For the measuring receiver with a peak detector with a bandwidth B_{imp} of 1 MHz, an impulse area (emf) of 1,4/B_{imp} mVs is required, that is, 1,4 nVs for a response equal to that of an unmodulated sine-wave signal tuned to the receive frequency having an emf with rms value of 2 mV [66 dB(µV)]. A pulse-modulated carrier having the required impulse area can be generated with the various pulse widths as shown in Table E.1:

Table E.1 – Carrier level for pulse-modulated signal of 1,4 nVs

Pulse width w_p/ns	Carrier level (e.m.f) $L_{carrier}$/dB(µV)
100	86
200	80

For a measuring receiver with a linear average detector, the impulse area (emf) equal to an unmodulated sine-wave signal at the receive frequency having an emf with rms value of 2 mV [66 dB(µV)] shall be 1,4/n mVs (n being the pulse repetition rate). For n = 50 000, the impulse area is 28 nVs, that is, 26 dB higher than for the peak measuring receiver with a B_{imp} of 1 MHz.

For a measuring receiver with an rms detector, the impulse area (emf) equal to an unmodulated sine-wave signal at the receive frequency having an emf with rms value of 2 mV [66 dB(µV)] shall be 44($B_3^{-1/2}$) µVs for pulse repetition rate of 1 kHz. For an impulse bandwidth B_{imp} of 1 MHz the corresponding B_3 is 700 kHz. Therefore, the required impulse area is 52,6 nVs, that is, 31,5 dB higher than for the peak measuring receiver with a B_{imp} of 1 MHz.

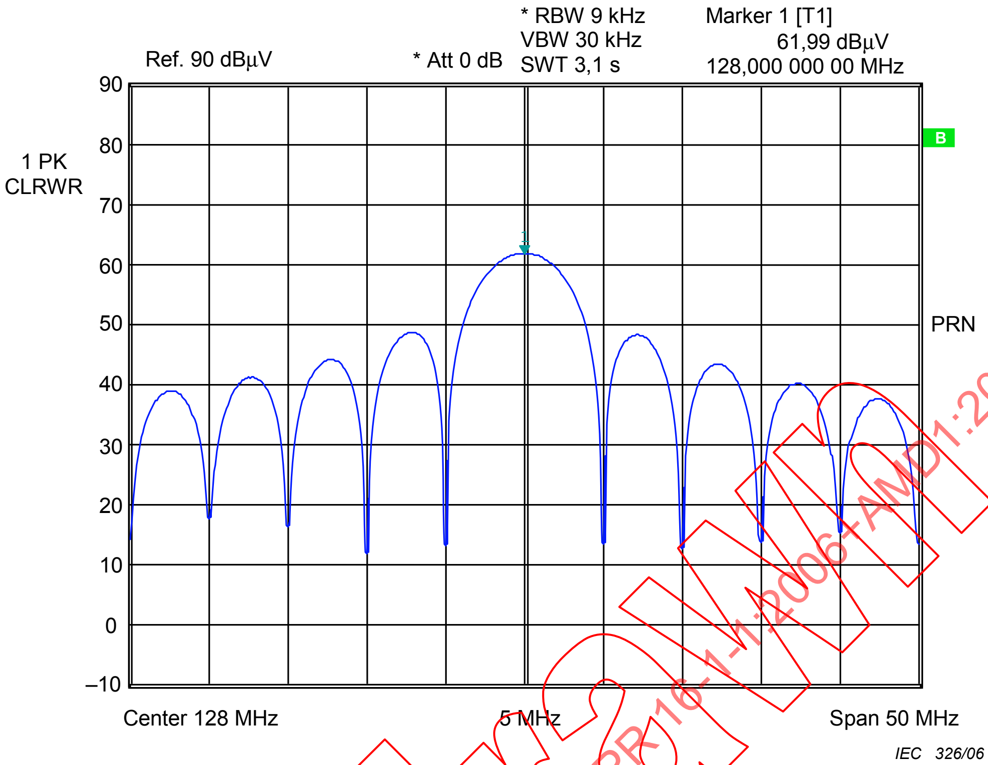


Figure E.3 – Example (spectrum) of a pulse-modulated signal with a pulse width of 200 ns

E.7 Measurement of the impulse bandwidth of a measuring receiver

The impulse bandwidth B_{imp} of a measuring receiver is defined as the peak value U_p (measured by the receiver) divided by the pulse spectral density D of the test pulse:

$$B_{imp} = U_p/D \tag{E.6}$$

If Up is measured in µV and D is given in µV/MHz, then B_{imp} will result in units of MHz. Both quantities, U_p and D, are assumed to be calibrated in rms values of an unmodulated sine wave signal, which is the case for CISPR measuring receivers.

The pulse spectral density D will frequently not be available as a precise reference quantity. In order to reduce the uncertainty of the impulse bandwidth measurement, methods 1 and 2 are using two measurements. Under certain circumstances, the selectivity curve of a measuring receiver can also be used to calculate B_{imp} (as described in method 3), since B_{imp} is the "voltage bandwidth" of the measuring receiver (not to be confused with the power bandwidth or equivalent noise bandwidth, which determines the rms value of Gaussian noise when using the rms detector of the measuring receiver). B_{imp} is determined by the selectivity curve of the IF filter, the (possibly non-linear) phase response of the filter and the video bandwidth of the receiver. It is wider than B_6, but there is no general factor for the relationship between B_{imp} and B_6 or B_3 of the receiver.

Method 1: Measurement by comparison of the responses of B_{imp} to two pulses with identical amplitude and width but with low and high pulse repetition frequencies (prf)

This method applies a pulse-modulated RF signal, with short pulse duration as shown in Figure E.4 and two different prfs. With the high prf (f_p » B_{imp}), the receiver can be tuned to the carrier frequency as shown in Figure E.5 and with the low prf f_p (f_p « B_{imp}), the spectrum will