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रेडियो व्यवधान एवं प्रतिरक्षा मापन उपकरण एवं पद्धतियाँ

भाग 1 रेडियो व्यवधान एवं प्रतिरक्षा मापन उपकरण

(पहला पुनरीक्षण)

Indian Standard

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS

PART 1 RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS

(First Revision)

ICS 33.100

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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NATIONAL FOREWORD

This Indian Standard (Part 1) (First Revision) which is identical with CISPR 16-1 (1993) 'Specification for radio disturbance and immunity measuring apparatus and methods — Part 1 : Radio disturbance and immunity measuring apparatus' [along with Amendment 1 (1997)] issued by Special Committee on Radio Interference (CISPR), was adopted by the Bureau of Indian Standards on the recommendation of the Electromagnetic Compatibility Sectional Committee and approval of the Electronics and Telecommunication Division Council.

This standard (Part 1) was originally published in 1982 and was largely based on CISPR 16(1977), Section 1. This revision is now being published to incorporate the latest developments in the technology in this field and also to align this standard with the latest edition of CISPR 16-1.

In the adopted standard, certain conventions are not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Amendment 1 (1997) to the above International Standard has been printed at the end.

CROSS REFERENCES

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (161) : 1990 International Electrotechnical Vocabulary (IEV) — Chapter 161 : Electromagnetic compatibility	IS 1885 (Part 64/Sec 1&2) : 1987 Electrotechnical vocabulary : Part 64 Electromagnetic compatibility, Section 1 General terms, Section 2 Specific terms	Technically Equivalent
IEC 315-3 : 1989 Methods of measurement on radio receivers for various classes of emission — Part 3 : Receivers for amplitude — Modulated sound-broadcasting emissions	IS 12193 (Part 2) : 1987 Methods of measurement on radio receivers for various classes of emission : Part 2 Radio frequency measurements on receivers for amplitude modulated sound broadcast emissions	do
IEC 315-4 : 1989 Methods of measurement on radio receivers for various classes of emissions — Part 4 : Radio frequency measurements on receivers for frequency modulated sound-broadcast emissions	IS 12193 (Part 3) : 1994 Methods of measurement on radio receivers for various classes of emission : Part 3 Radio frequency measurements on receivers for frequency modulated sound broadcast emissions	Identical

(ii)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
CISPR 16-2 (1996) Specification for radio disturbance and immunity measuring apparatus and methods — Part 2 : Methods of measurement of disturbances and immunity	IS 10052 (Part 2) : 1999 Specification for radio disturbance and immunity measuring apparatus and methods : Part 2 Methods of of measurement of disturbances and immunity (*first revision*)	Identical

The concerned Technical Committee responsible for the preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard:

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

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

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard except the figures.

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Indian Standard

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS

PART 1 RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS

(First Revision)

1 General

1.1 *Scope*

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

The receiver types covered include the following:

a) the quasi-peak measuring receiver,

b) the peak measuring receiver,

c) the average measuring receiver,

d) the r.m.s. measuring receiver.

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

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

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

1.2 *Normative references*

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of CISPR 16. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of CISPR 16 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

CISPR 16-2: *Specification for radio disturbance and Immunity measuring apparatus and methods. Part 2: Methods of disturbance and immunity measurements* (to be published)

CISPR 16-3: *Specification for radio disturbance and Immunity measuring apparatus and methods. Part 3* (under consideration)

IEC 50(161): 1990, *International Electrotechnical Vocabulary (IEV), Chapter 161: Electromagnetic compatibility*

IEC 315-3: 1989, *Methods of measurement or radio receivers for various classes of emissions, part 3: Receivers for amplitude – modulated sound-broadcasting emissions*

IEC 315-4: 1989, *Methods of measurement ou radio receivers for various classes of emissions, part 4: Radio-frequency measurements on receivers for frequency modulated sound-broadcasting emissions*

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

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

1.3 *Definitions*

For the purpose of this part of CISPR 16, the following definitions apply. Also see IEC 50(161).

1.3.1 *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.

1.3.2 *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 in annex A for further information).

1.3.3 *Impulse area (IS)*

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

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

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) = 2×10^6 *IS* (µVs) applies.

1.3.4 *Electrical charge time constant (T_C)*

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

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

1.3.5 *Electrical discharge time constant (T_D)*

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

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

1.3.6 *Mechanical time constant (T_M) of a critically damped indicating instruments*

$$T_M = T_L / 2\pi$$

where

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

NOTES

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.

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 $\alpha T = 0,35\alpha_{max}$.

1.3.7 *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).

1.3.8 *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*).

1.3.9 *Asymmetric voltage*

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

1.3.10 *Unsymmetric voltage*

The amplitude of the vector voltage, *Va* or *Vb* defined in 1.3.8 and 1.3.9. This is the voltage measured by the use of an artificial mains V-network.

1.3.11 *CISPR indicating range*

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

SECTION 1: MEASURING APPARATUS

2 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).

2.1 *Input impedance*

The input circuit of measuring receivers shall be unbalanced. For receiver control settings within the CISPR indicating range, the input impedance shall be nominally 50 Ω with a 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.

2.2 *Fundamental characteristics*

The responses to pulses as specified in 2.4 are calculated on the basis of the measuring receivers having the following fundamental characteristics:

Table 1 – Fundamental characteristics of quasi-peak receivers

Characteristics	Frequency band		
	Band A 9 kHz to 150 kHz	Band B 0,15 MHz to 30 MHz	Bands C and D 30 MHz to 1 000 MHz
Bandwidth at the –6 dB points B_6, in kHz	0,22	9	120
Detector electrical charge time constant, in ms	45	1	1
Detector electrical discharge time constant, in ms	500	160	550
Mechanical time constant of critically damped indicating instrument, in ms	160	160	100
Overload factor of circuits preceding the detector, in dB	24	30	43,5
Overload factor of the d.c. amplifier between detector and indicating instrument, in dB	6	12	6

NOTES

1 The definition of mechanical time constant (see 1.3.6) 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.

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 2.4.

2.3 *Sine-wave voltage accuracy*

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

2.4 *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.

2.4.1 *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.

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

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

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

2.4.2 *Variation with repetition frequency (relative calibration)*

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

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

Table 3 – Pulse response of quasi-peak receivers

Repetition frequency Hz	Relative equivalent level in dB of pulse for stated band			
	Band A 9 kHz to 150 kHz	Band B 0,15 MHz to 30 MHz	Band C 30 MHz to 300 MHz	Band D 300 MHz to 1 000 MHz
1 000	Note 4	–4,5 ± 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 (réf.)	–	–	–
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 ± 1,5	–	–	–
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*

NOTES

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

2 The relationships between the pulse responses of a quasi-peak receiver and receivers with other detector types are given in 3.4, 4.4.1, and 5.4.1.

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.

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.

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

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.

2.5 *Selectivity*

2.5.1 *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.

2.5.2 *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.

2.5.3 *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.

2.5.4 *Other spurious responses*

The ratio of the input sine-wave voltage at frequencies other than those specified in 2.5.2 and 2.5.3 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 2.7.2.

2.6 *Limitation of intermodulation effects*

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

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

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

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

Connect the sine-wave generator output direct to the measuring receiver input and adjust for a convenient reading. Substitute the pulse generator for the sine-wave generator and adjust for the same reading. The pulse repetition frequency shall be 25 Hz for band A and 100 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.

2.7 *Limitation of receiver noise and internally generated spurious signals*

2.7.1 *Random noise*

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

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

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

2.7.2 *Continuous wave*

Where more than one intermediate frequency is used, the existence of spurious responses as described in the note to 2.5.4 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 2.7.1 when tested as described in 2.7.1, except that the attenuation in the intermediate stages shall be introduced after the last mixer stage.

2.8 *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 1.3.11.

The screening of the receiver shall be such that when it is immersed in an ambient electromagnetic field of 3 V/m unmodulated at any frequency in the range 9 kHz to 1 000 MHz, an error of not greater than 1 dB is produced at the maximum and minimum of the CISPR indicating range as specified by the manufacturer at the receiver. In cases where a measuring receiver does not achieve 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 length well-screened coaxial cable (e.g. semi-rigid) through a coaxial feed-through connector 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 3 V/m electromagnetic field shall differ by not more than 1 dB from the meter indication when the field is absent.

2.9 *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.

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

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

3.1 *Input impedance*

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

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

3.2 *Fundamental characteristics*

3.2.1 *Bandwidth*

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

Table 5 – Bandwidth requirements

Frequency range	Bandwidth B_6	Preferred BW
9 kHz to 150 kHz (band A)	100 Hz to 300 Hz	200 Hz
0,15 MHz to 30 MHz (band B)	8 kHz to 10 kHz	9 kHz
30 MHz to 1 000 MHz (bands C and D)	100 kHz to 500 kHz	120 kHz

NOTE - Since the response of a peak measuring receiver to non-overlapping pulses is proportional to its impulse bandwidth, either the actual bandwidth is quoted in the result or the level may be quoted as that "in a 1 MHz bandwidth" calculated by dividing the measured value by the impulse bandwidth in MHz (see 1.3.2). For other types of broadband disturbance this procedure would introduce an error.

3.2.2 *Charge and discharge time constants ratio*

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

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

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

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

3.2.3 *Overload factor*

For peak measuring receivers, the overload factor need not be so great as for other types of measuring receiver. For most direct-reading detectors, the overload factor need be only a little greater than unity. The overload factor shall be adequate for the time-constants used (see 3.2.2).

3.3 *Sine-wave voltage accuracy*

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

3.4 *Response to pulses*

The response of the measuring receiver to pulses of impulse area $1,4/B_{imp}$ mVs (where B_{imp} is in hertz) e.m.f. at 50 Ω source impedance shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of r.m.s. value 2 mV (66 dB(μV)). The source impedances of the pulse generator and the signal generator shall both be the same. The pulses shall have a uniform spectrum according to table 2 of 2.4.1.

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

NOTES

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

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

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

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

3.5 *Selectivity*

Since the bandwidth requirements of 3.2.1 allow variations from the bandwidths given in figures 2a, 2b and 2c, these selectivity curves apply to peak measuring receivers as regards shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in figure 2a).

The requirements of 2.5.2, 2.5.3 and 2.5.4 apply.

3.6 *Inter-modulation effects, receiver noise, and screening*

The requirements of 2.6, 2.7, and 2.8 apply.

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

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

4.1 *Input impedance*

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

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

4.2 *Fundamental characteristics*

4.2.1 *Bandwidth*

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

Table 7 – Bandwidth requirements

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

4.2.2 *Overload factor*

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

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

4.3 *Sine-wave voltage accuracy*

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

4.4 *Response to pulses*

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

4.4.1 *Amplitude relationship*

The response of the measuring receiver to pulses of repetition rate n Hz and impulse area e.m.f. at 50 Ω source impedance equal to 1,4/n mVs, shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. of r.m.s. value 2 mV (66 dB(μV)). The source impedances of the pulse generator and the signal generator shall both be the same. The pulses shall have a uniform spectrum according to table 2 of 2.4.1. 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 ±1,5 dB is permitted on the sine-wave voltage level.

NOTES

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

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

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

Frequency range of measuring receiver	Ratio quasi-peak/average indications (dB) for pulse repetition rate			
	25 Hz	100 Hz	1 000 Hz	10 000 Hz
9 kHz to 150 kHz (band A)	12,4	4,5	–	–
0,15 MHz to 30 MHz (band B)	–	32,9	17,4	–
30 MHz to 1 000 MHz (bands C and D)	–	50,1	38,1	20,8

4.4.2 *Variation with repetition frequency*

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

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

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

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

4.5 *Selectivity*

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

The requirements of 2.5.2, 2.5.3 and 2.5.4 apply.

4.6 *Inter-modulation effects, receiver noise, and screening*

The requirements of 2.6, 2.7, and 2.8 apply.

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

5.1 *Input impedance*

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

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

5.2 *Fundamental characteristics*

5.2.1 *Bandwidth*

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

5.2.2 *Overload factor*

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

NOTES

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

2 Annex A describes the calculation for the overload factor.

5.3 *Sine-wave voltage accuracy*

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

5.4 *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.

5.4.1 *Amplitude relationship*

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

NOTES

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

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

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

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

5.4.2 *Variation with repetition frequency*

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

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

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

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

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

5.5 *Selectivity*

Since the bandwidth requirements of 5.2.1 allow variations from the bandwidths given in figures 2a, 2b and 2c, these selectivity curves apply to r.m.s. measuring receivers as regards shape only, and the frequency axis shall be scaled accordingly. For example, $B_6/2$ corresponds to 100 Hz in figure 2a.

The requirements of 2.5.2, 2.5.3 and 2.5.4 apply.

5.6 *Inter-modulation effects, receiver noise, and screening*

The requirements of 2.6, 2.7 and 2.8 apply.

6 Spectrum analyzers and scanning receivers

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

Spectrum analyzers and scanning receivers intended for the measurement of disturbance in the frequency range 9 kHz to 1 000 MHz shall comply with the performance requirements specified in clauses 2, 3 or 4.

6.2 *Spectrum analyzers for the frequency range 1 GHz to 18 GHz*

Requirements for spectrum analyzers in the frequency range 1 GHz to 18 GHz are listed below.

a) The bandwidth B_6 shall be 125 kHz ± 25 kHz.

b) Spurious response shall be at least 40 dB below the response at the instantaneous tuned frequency.

NOTE - This may be achieved by using a preselector.

c) The screening effectiveness for the frequency range of 9 kHz to 1 000 MHz shall comply with the requirements of 2.8.

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

NOTES

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

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

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

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

7 Audio-frequency voltmeter

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

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

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

7.1 *Fundamental characteristics*

7.1.1 *Input impedance*

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

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

* IEC 315-3 for a.m. receivers.
IEC 315-4 for f.m. receivers.

Table 11 – Balance requirement

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

7.1.2 *Sensitivity*

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

7.1.3 *Frequency response*

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

a) frequency response of the wideband amplifier: 3 dB at 16 Hz and 16 kHz

b) telephone psophometric filter: see figure 5*

c) sound programme psophometric filter: see figure 6**

7.2 *Sine-wave voltage accuracy*

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

7.3 *Screening*

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

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

7.4 *Requirements for use as a quasi-peak meter*

The sound programme psophometric filter shall be used.

7.4.1 *Quasi-peak meter fundamental characteristics*

The response to pulses as specified in 7.4.2 and 7.4.3 are calculated on the basis of the following nominal fundamental characteristics.

– Overload factor 30 dB

– Charging time constant 1 ms

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

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

– Discharging time constant 160 ms

– Mechanical time constant of the critically damped indicating instrument 160 ms

NOTE - When used with a measuring receiver, the time constants shall be adjusted to suit the requirements of 7.4.2 and 7.4.3.

7.4.2 *Response to pulses*

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

7.4.3 *Variation with repetition frequency*

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

Table 12 – Pulse response requirement

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

7.5 *Requirements for use as an r.m.s. meter*

7.5.1 *R.M.S. meter fundamental characteristic*

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

7.5.2 *Response to pulses*

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

7.5.3 *Variation with repetition frequency*

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

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

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

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

8 Reserved

9 Reserved

10 Reserved

SECTION 2: ANCILLARY APPARATUS

11 Artificial mains networks

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

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

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

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

11.1 *Network impedance*

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

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

The impedance of each of the mains conductors of the network shall comply with 11.2, 11.3, 11.4, 11.5, or 11.6 as appropriate, for any value of external impedance, including a short circuit or the RF filter described in 11.7, connected between the corresponding mains terminal and reference earth. This requirement shall be met at all temperatures which the network may reach under normal conditions for continuous currents up to the specified maximum. The requirement shall also be met for peak currents up to the specified maximum.

11.2 *50 Ω/50 μH + 5 Ω artificial mains V-network (for use in the frequency range 9 kHz to 150 kHz)*

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

NOTE - This network may be constructed such that it can meet the combined impedance requirements of this subclause and 11.3.

11.3 *50 Ω/50 μH artificial mains V-network (for use in the frequency range 0,15 MHz to 30 MHz)*

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

NOTE - The 50 Ω/50 μH + 5 Ω artificial mains V-network of 11.2 may also meet the impedance requirement of this subclause.

11.4 *50 Ω/5 μH + 1 Ω artificial mains V-network (for use in the frequency range 150 kHz to 100 MHz)*

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

11.5 *150 Ω artificial mains V-network (for use in the frequency range 150 kHz to 30 MHz)*

The network shall have an impedance of magnitude 150 ± 20 Ω with a phase angle not exceeding 20°.

11.6 *150 Ω artificial mains delta-network (for use in the frequency range 150 kHz to 30 MHz)*

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

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

11.6.1 *Balance of the 150 Ω artificial mains delta-network*

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

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

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

11.7 *Isolation*

To ensure that at any test frequency unwanted signals existing on the supply mains do not affect the measurement, an additional RF low-pass filter may be required, inserted between the artificial mains network and the supply mains. With this filter inserted, the impedance requirements given in 11.2, 11.3, 11.4, 11.5, and 11.6 shall be met. The components forming this filter shall be enclosed in a metallic screen directly connected to the reference earth of the measuring system.

11.8 *Current carrying capacity and series voltage drop*

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

11.9 *Modified reference earth connection*

The measurement of some types of equipment may require the insertion of an impedance in the reference earth conductor in the artificial mains networks in 11.2 and 11.3 following the requirements of the related product publications. This is inserted at point X marked in the reference earth lead in figures 23 and 24, respectively. The impedance to be inserted is either a 1,6 mH inductor or an impedance conforming to the impedance requirement of 11.2 or 11.3, as appropriate for the frequency range.

NOTE - For safety reasons, the 5 Ω resistor mentioned in 11.2 should be omitted.

12 Current and voltage probes

12.1 *Current probes*

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

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

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

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

12.1.1 *Construction*

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

Annex J contains some typical constructions of current probes.

12.1.2 *Characteristics*

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

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

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

12.2 *Voltage probe*

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

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

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

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

13.1 *General*

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

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

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

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

13.2 *Construction*

The absorbing clamp shall consist of three parts as follows:

a) a broadband RF current transformer;

b) a broadband RF power absorber and impedance stabilizer for the lead under measurement;

c) an absorbing sleeve or assembly of ferrite rings to reduce RF current on the surface of the coaxial cable from the current transformer to the measuring receiver.

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

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

13.3 *Characteristics*

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

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

Requirements for absorber attenuation are under consideration.

14 Disturbance analyzers

Disturbance analyzers are used for the automatic assessment of the amplitude, rate and duration of disturbances due for example to switching operations.

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

14.1 *Fundamental characteristics*

The analyzer shall be equipped with a channel to measure the duration of disturbances; the input of this channel shall be connected to the i.f. output of the measuring receiver; the accuracy of duration measurement shall be not worse than ±5 %.

The analyzer shall be equipped with a channel to assess the quasi-peak amplitude of a disturbance. The combination of the measuring receiver and the disturbance analyzer shall comply in all respects with the requirements of clause 2.

The analyzer shall be capable of indicating the following information:

a) the number of clicks (see note 1) of duration equal to or less than 10 ms which exceed a reference level pre-set in the receiver;

b) the number of clicks of duration greater than 10 ms but equal to or less than 200 ms that exceed the reference level set in a);

c) the incidence of more than two clicks occurring in any 2 s period and exceeding the reference level set in a);

d) the incidence of more than five clicks each of duration equal to or less than 10 ms and exceeding the reference level set in a) in any 1 min period (see note 2);

e) the total duration of disturbance other than clicks that exceeds the reference level set in a);

f) the duration of test in minutes;

g) the number of switching operations made by the equipment under test.

NOTES

1 The definition of a 'click' is given in CISPR 14.

2 This function is not required to meet the provisions of CISPR 14.

3 An example of a disturbance analyzer is shown in block diagram in figure 11.

The tests for compliance with the requirements of 14.1 are given in 14.2. The disturbance analyzer shall comply with the "required results" listed in tables 13, 14 and 15. Figure 12 presents in a graphical form the waveforms listed in tables 13, 14 and 15.

Table 13 – Disturbance analyzer performance check waveforms

Test No.	1		2		3		4	5
	Amplitude in intermediate frequency dB		Amplitude on quasi-peak meter (reference midpoint of meter scale) dB[1]		Duration of pulses ms		Separation of pulses or periodicity ms	Results
	Pulse 1	Pulse 2	Pulse 1	Pulse 2	Pulse 1	Pulse 2		
1	–	–	5	–	9,5	–	–	1 click ≤ 10 ms
2	–	–	5	–	10,5	–	–	1 click > 10 ms
3	–	–	5	–	190,0	–	–	1 click > 10 ms
4	–	–	5	–	210,0	–	–	other than clicks
5	–	–	5	5	30,0	30,0	180	other than clicks
6	–	–	5	5	30,0	30,0	130	1 click > 10 ms
7	–	–	5	5	30,0	30,0	210	2 clicks >10 ms
8	–	–	5	–	30,0	–	Periodicity 210	> 2 clicks within 2 s
9	–	–	5	–	9,5	–	Periodicity 210	> 5 clicks within 1 min
10[2]	–	–	1	–	190,0	–	–	1 click > 10 ms
11[2]	–	–	1	–	9,5	–	–	1 click ≤ 10 ms
12	–	–	1		0,11	–	Periodicity 10	other than clicks
13	–	–	1	–	0,41	–	–	1 click ≤ 10 ms
14	–	–	2,5[3]	25	30,0	30,0	230	1 click > 10 ms
15	–	2	25,0	-2,5[3]	190,0	30,0	1 188[4]	2 clicks > 10 ms[5]
16	–	2	25,0	-2,5[3]	190,0	30,0	1 312[4]	1 click >10 ms

NOTES

1 Pulse amplitudes measured individually.

2 Background noise level 2,5 dB below quasi-peak threshold level.

3 These lower levels shall be set such that the intermediate frequency threshold is exceeded but the quasi-peak threshold is not exceeded.

4 1 710 and 2 090 respectively for CISPR quasi-peak measuring apparatus for the frequency range above 30 MHz.

5 If these two pulses were to be measured as separate disturbances, only one click would be registered.

Table 14 – Performance checks for high-level pulses

Test No.	Amplitude of pulses (reference mid-point of meter scale) dB			Duration of pulses ms			Separation of pulses ms		Results
	1 In intermediate frequency	2 In quasi-peak	3 Intermediate frequency	1	2	3	Pulses 1 and 2	Pulses 2 and 3	
17	2	44	2	1	2	1	169	190	other than clicks*
18	2	44	–2	1	2	1	169	190	1 click

* If these three pulses were to be measured as separate disturbances only one click would be registered.

Table 15 – Additional tests

Test No.	Amplitude of pulses (reference mid-point of quasi-peak meter) dB				Duration of pulses ms				Separation of pulses ms			Results
	1	2	3	4	1	2	3	4	Pulses 1 and 2	Pulses 2 and 3	Pulses 3 and 4	
19	5	5	5	5	30	30	30	30	240	1 800	250	4 clicks
20	5	5	5	5	30	30	30	30	370	1 620	250	4 clicks; accumulation condition, more than two clicks within 2 s
21	5	5	5	5	30	30	30	30	1 780	210	250	4 clicks; accumulation condition, more than two clicks within 2 s
22	5	5	5	5	30	30	30	30	1 860	130	250	3 clicks

14.2 *Method of test for compliance*

The disturbance analyzer is connected to the quasi-peak measuring receiver tuned to a convenient frequency. A c.w. signal and a pulsed c.w. signal both at the tuned frequency of the receiver, and a white-noise signal covering the receiver bandwidth at the tuned frequency are required.

The pulsed c.w. signal source shall provide one to four independently variable pulses. The rise times of the pulses shall be not longer than 40 µs. The pulse durations shall be variable between 110 µs and 210 ms and the amplitudes variable over a 44 dB range. Any background noise of the pulsed c.w. signal shall be at least 20 dB below the reference level used in step 1 in the test measured on the receiver quasi-peak meter.

An oscilloscope is connected to the intermediate frequency output of the quasi-peak receiver to measure the level and the duration of the pulsed signal.

The test procedure is as follows:

1) The c.w. signal is connected to the input of the measuring receiver used in conjunction with the disturbance analyzer. The amplitude of the c.w. signal is adjusted to a level well above the noise but below the overloading point of the receiver. The receiver sensitivity (attenuator) control is adjusted to bring the meter indication to the reference (0 dB) point on the scale. The corresponding level of the c.w. signal at the i.f. output of the receiver constitutes the IF reference level.

2) The pulsed c.w. signal is connected to the input of the measuring receiver. For tests 10 and 11 the white noise signal is added to the pulsed c.w. signal. The nature of the signal is given in tables 13, 14 and 15. In table 13 the signal contains one or two pulses, the group occurring single-shot or recurring, in table 14 three pulses single-shot, and in table 15 four pulses single-shot. The amplitudes of the pulses shown in column 1 of table 13 and of the pulses 1 and 3 shown in table 14 are measured using the oscilloscope connected to the IF output of the measuring receiver. The amplitudes of the other pulses are measured using the quasi-peak meter of the receiver. The levels shall be relative to the respective RF and IF reference levels established in the previous paragraph.

All duration measurements are made in the IF of the measuring receiver using the oscilloscope.

The tests shall be performed in numerical order.

15 Antennas for measurement of radiated radio disturbance

The antenna and the circuits inserted between it and the measuring receiver shall not appreciably affect the overall characteristics of the measuring receiver. When the antenna is connected to the measuring receiver, the measuring system shall comply with the bandwidth requirements of Section 1 appropriate to the frequency band concerned.

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

15.1 *Accuracy of field-strength measurements*

The accuracy of field-strength measurement of a uniform field of a sine-wave shall be better than ±3 dB when an antenna meeting the requirements of this subclause is used with a measuring receiver meeting the requirements of section 1.

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

15.2 *Frequency range 9 kHz to 150 kHz*

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

15.2.1 *Magnetic antenna*

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

15.2.2 *Balance of antenna*

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

15.3 *Frequency range 150 kHz to 30 MHz*

15.3.1 *Electric antenna*

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

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

15.3.2 *Magnetic antenna*

For the measurement of the magnetic component of the radiation, an electrically-screened loop antenna, as described in 15.2.1 shall be used.

15.3.3 *Balance of antenna*

If a balanced electric or a magnetic antenna is used, it shall comply with the requirement of 15.2.2.

15.4 *Frequency range 30 MHz to 300 MHz*

15.4.1 *Electric antenna*

The reference antenna shall be a balanced dipole.

15.4.1.1 *Balanced dipole*

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

15.4.1.2 *Shortened dipole*

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

a) the total length is greater than 1/10 of a wavelength at the frequency of measurement;

b) it is connected to a cable sufficiently well matched at the receiver end to ensure a voltage standing wave ratio (v.s.w.r.) on the cable of less than 2.0 to 1. The calibration shall take account of the v.s.w.r.;

c) it has a polarization discrimination equivalent to that of a tuned dipole (see 15.4.2). To obtain this, a balun may be helpful;

d) for determination of the measured field strength, a calibration curve (antenna factor) is determined and used in the measuring distance (i.e., at a distance of at least three times the length of the dipole);

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

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

15.4.1.3 *Broadband antenna*

A broadband antenna may be used, provided that it meets the requirements given in 15.5.2 for a complex antenna.

15.4.2 *Balance of antenna*

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

15.5 *Frequency range 300 MHz to 1 000 MHz*

15.5.1 *Electric antenna*

If a dipole antenna is used, it shall meet the requirements of 15.4.1.1 and 15.4.2.

15.5.2 *Complex antenna*

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

a) The antenna shall be substantially plane polarized. This shall be checked in the same manner as for the balance of a simple dipole antenna.

b) The main lobe of the radiation pattern of the antenna shall be such that the response in the direction of the direct ray and that in the direction of the ray reflected from the ground do not differ by more than 1 dB.

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

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

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

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

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

where

h_1 is the measuring antenna height;

h_2 is the height of the device under test;

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

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

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

c) The voltage standing-wave ratio of the antenna with the antenna feeder connected and measured from the receiver end shall not exceed 2,0 to 1.

d) A calibration factor shall be given making it possible to fulfil the requirements of 15.1.

15.6 *Frequency range 1 GHz to 18 GHz*

For specific measurements, the relevant antenna requirements are to be given.

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

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

16.1 *Open area test site*

Disturbance field-strength measurements are normally performed at an open area test site. Open area test sites are areas characteristic of cleared level terrain. Such test sites shall be void of buildings, electric lines, fences, trees, etc. and free from underground cables, pipelines, etc, except as required to supply and operate the equipment under test (EUT). Refer to annex L for specific construction recommendations for open area test sites for electromagnetic field tests in the range of 30 MHz to 1 GHz. The site validation procedure for open area test sites is given in 16.6 with further details in annex G. Annex M contains the acceptability criterion.

16.2 *Weather protection enclosure*

Weather protection is desirable if the test site is used throughout the year. A weather protection structure could either protect the whole test site including EUT and field strength measuring antenna or the EUT only. The materials used shall be RF transparent in order to cause no undesirable reflections and attenuation of the emitted field from the EUT.

The structure shall be shaped to allow easy removal of snow, ice or water. For further details, see annex L.

16.3 *Obstruction-free area*

For open area test sites, an obstruction-free area surrounding the EUT and field-strength measuring antenna is required. The obstruction-free area should be free from significant scatterers of electromagnetic fields, and should be large enough so that scatterers outside the obstruction-free area will have little effect on the fields measured by the field-strength measuring antenna. To determine the adequacy of this area, site validation tests should be performed.

Since the magnitude of the field scattered from an object depends on many factors (size of the object, distance from the EUT, orientation with respect to the EUT, conductivity and permittivity of the object, frequency, etc.), it is impractical to specify a reasonable obstruction-free area which is necessary and sufficient for all applications. The size and shape of the obstruction-free area are dependent upon the measurement distance and whether or not the EUT will be rotated. If the site is equipped with a turntable, the recommended obstruction-free area is an ellipse with the receiving antenna and EUT at the two foci and having a major axis equal to twice the measurement distance and a minor axis equal to the product of the measurement distance and the square root of 3 (see figure 14).

For this ellipse, the path of the undesired ray reflected from any object on the perimeter is twice the length of the direct ray path between the foci. If a large EUT is installed on the turntable, the obstruction-free area must be expanded so that the obstruction clearance distances exist from the perimeter of the EUT.

If the site is not equipped with a turntable, that is, the EUT is stationary, the recommended obstruction-free area is a circular area such that the radial distance from the boundary of the EUT to the boundary of the area is equal to the measurement distance multiplied by 1,5 (see figure 15). In this case, the antenna is moved around the EUT at the separationdistance.

The terrain within the obstruction-free area should be flat. Small slopes needed for adequate drainage are acceptable. The flatness of the metallic ground plane, if used, is discussed in L.2 of annex L. Measuring apparatus and test personnel should be situated outside the obstruction free area.

16.4 *Ambient radio frequency environment of a test site*

The ambient radio frequency levels at a test site shall be sufficiently low compared to the levels of measurements to be performed. The quality of the site in this respect may be assessed in four categories, listed below in their order of merit:

a) the ambient emissions are 6 dB or more below the measurement levels,

b) some ambient emissions are within 6 dB of the measurement levels,

c) some ambient emissions are above the measurement levels, but are either aperiodic (i.e., sufficiently long in time between transmissions to allow a measurement to be made) or continuous, but only on limited identifiable frequencies,

d) the ambient levels are above the measurement levels over a large portion of the measurement frequency range and occurring continuously.

The selection of a test site should ensure that the accuracy of the measurement is maintained given the environment and the degree of engineering skill available.

NOTE - For perfect results, an ambient level 20 dB below the emission level measured is recommended.

16.5 *Ground plane*

The ground plane may be composed of a wide range of material from earth to highly conductive, metallic material. The plane can be at earth level or elevated on a suitably sized platform or roof site. A metal ground plane is preferred, but for certain equipment and applications, it may not be recommended by certain product publications. Adequacy of the metal ground plane will be dependent on whether the test site meets the site validation requirements in 16.6. If no metallic material is used, caution is required to select a site that does not change its reflective characteristics with time, weather condition, or, due to buried metallic material such as pipes, conduits, and non-homogeneous soil. Such sites generally give different site attenuation characteristics compared to those with metallic surfaces.

16.6 *Open area site validation procedure*

The validation procedure and the requirements for the normalized site attenuation given here are used to qualify a test site when a metallic ground plane is specified. For other test sites, the validation procedure is of an informative nature, and will in general also identify possible site irregularities that should be investigated. The validation procedure is not applicable to absorber lined rooms. Such a procedure requires more detailed specifications and is under consideration.

The validation of an open area test site is performed with two antennas oriented horizontally and vertically with respect to the ground, as shown in figures 16 and 17, respectively. The open area site attenuation is obtained from the ratio of the source voltage (V_i) connected to a transmitting antenna and the received voltage (V_r) as measured on the receiving antenna terminals. The voltage measurements are performed in a 50 Ω system. Suitable corrections for cable losses is required if V_r and V_i are not measured at the input and output of the transmit and receive antenna, respectively. This site attenuation ratio is then divided by the product of the antenna factors for the two antennas used. The resulting answer is the normalized site attenuation (NSA) and is expressed in dB. *The site is considered suitable when the measured vertical and horizontal NSA's are within ±4 dB of the values given in tables G.1, G.2, and G.3, as appropriate.* If the ±4 dB criterion is exceeded, the test site must be investigated per clause G.4 of annex G.

NOTE - The basis for the 4 dB site acceptability criterion is given in annex M.

The deviation between a measured NSA value and the theoretical value shall not be used as a correction for a measured EUT field strength. This procedure shall be used only for validating a test site.

Table G.1 is used for broadband antennas such as biconical and log periodic arrays both horizontally and vertically aligned with respect to the ground plane. Table G.2 is for tuned half-wave dipoles aligned horizontally with respect to the ground plane. Table G.3 is for tuned half-wave dipoles vertically aligned with respect to the ground plane. Note that in table G.3, there are restrictions in the scan height h_2. This takes into account the fact that the lowest tip of the receive dipole is kept 25 cm or more from the ground plane.

NOTE - The reason for the different tables G.1 and G.2/G.3 is that different geometrical parameters are chosen for a broadband antenna and a tuned half-wave dipole, primarily because of practical restrictions needed for the latter.

NSA for frequencies other than those shown in the tables may be found using straight-line interpolation between the tabulated values.

The legend for each table is as follows:

- R Horizontal separation distance between the projection of the transmit and receive antennas on the ground plane (metres).
- h_1 Height of the centre of the transmit antenna above the ground plane (metres).
- h_2 Range of heights of the centre of the receive antenna above the ground plane (metres). The maximum received signal in this height scan range is used for NSA measurements.
- f_m Frequency in MHz.
- A_N NSA (see equation 1, below).

NOTE - The spacing R between log-periodic array antennas is measured from the projection on to the ground plane of the mid-point of the longitudinal axis of each antenna.

It is recommended that horizontal NSA measurements be performed first. Since such measurements are less sensitive than that for vertical polarization in finding test anomalies, the measured NSA should readily be within ±4 dB of that shown in tables G.1, G.2 and G3. If not, recheck measurement technique, instrumentation drift and antenna factor calibrations. If the ±4 dB criterion is still exceeded, a significant site anomaly is present which should be readily apparent and corrective action taken before proceeding to the vertical polarization NSA measurement.

16.6.1 *General NSA measurement*

For each polarization measurement, the NSA procedure requires two different measurements of V_R which is the voltage received. The first reading of V_R is with the two coaxial cables disconnected from the two antennas and connected to each other via an adapter. The second reading of V_R is taken with the coaxial cables reconnected to their respective antennas and the maximum signal measured when the receive antenna is scanned in height. (1-4 m for 3 m and 10 m separation distances and either 1-4 m or 2-6 m for the 30 m separation.) For both of these measurements, the signal source voltage, V_i, is kept constant. The first reading of V_R is called V_{DIRECT} and the second is V_{SITE}. These are used in the following equation (1) for the measured NSA, A_N; all terms are in dB.

$$A_N = V_{DIRECT} - V_{SITE} - AF_T - AF_R - \Delta AF_{TOT} \quad (1)$$

where

AF_T is the transmit antenna factor;

AF_R is the receive antenna factor;

ΔAF_{TOT} is the mutual impedance correction factor.

Note that the first two terms represent the actual measurement of site attenuation, i.e., $V_{DIRECT} - V_{SITE}$ is equal to the classical view of site attenuation, which is constituted by the insertion loss of the propagation path with the inclusion of the properties of the two antennas used. Theoretical values for ΔF_{TOT} are given in table G.4 AF_T and AF_R shall be measured.

Note that: $V_{DIRECT} = V_I - C_T - C_R$

where

C_T and C_R are the cable losses which do not need to be measured separately. The mutual impedance correction factor in table G.4 applies only to the recommended site geometry of 3 m separation, horizontal polarization and the use of half-wavelength tuned dipoles.

To accomplish these NSA measurements, two techniques can be used, depending on the instrumentation available and whether a broadband or tuned dipole is used. Both methods give essentially equal results if used correctly as outlined in annex G. Briefly, each method is described as follows:

a) *Discrete frequency method*

For this method, specific frequencies given in tables G.1, G.2 or G.3 are measured in turn. At each frequency the receive antenna is scanned over the height range given in the appropriate table to maximize the received signal. These measured parameter values are inserted in equation (1) to obtain the measured NSA. Annex G contains a suggested procedure approach to record the data, calculate the measured NSA, and then compare it with the theoretical NSA.

b) *Swept frequency method*

For this method, measurements using broadband antennas may be made using automatic measuring equipment having a peak hold (maximum hold), storage capability, and a tracking generator. In this method both antenna height and frequency are scanned or swept over the required ranges. The frequency sweep speed shall be much greater than the antenna height scan rate. Otherwise the procedure is the same as in a). A detailed procedure is given in annex G.

16.6.2 *Antenna factor determination*

Accurate antenna factors are necessary in measuring NSA. In general, antenna factors provided with the antenna are inadequate unless they are specifically or individually measured. Linearly polarized antennas are required. A useful antenna calibration method is contained in annex G. Manufacturer's antenna factors may account for losses due to the balun among other features. If a separate balun or any integrally associated cables are used, their effects must be accounted for. The formula to use for tuned half-wave dipoles is also contained in annex G.

16.6.3 *Site attenuation deviations*

If measurements of NSA deviate by more than ±4 dB, several items should be re-checked first:

a) measurement procedure;

b) accuracy of antenna factors;

c) drift in signal source or accuracy of receiver or spectrum analyzer input attenuator and reading.

If no errors are found in a), b) and c), then the site is at fault and detailed investigation of possible causes of site variability should be made. Annex M contains the errors that can occur with NSA measurements.

Note that since the vertical polarization is generally the more critical measurement, site anomalies should be investigated using this more sensitive measurement rather than the horizontal polarization results. Key items to investigate include:

a) ground plane size and construction inadequacy;

b) objects at the perimeter of the site that may be causing undesired scattering;

c) all-weather cover;

d) ground plane discontinuity at the turntable circumference when the turntable surface is conductive and at the same elevation as the ground plane;

e) thick dielectric ground plane covers;

f) openings in ground plane for stairways.

17 Reverberating chamber for total radiated power measurement

For some types of equipment operating in the microwave frequency range, because of the existence of complex three-dimensional radiation patterns which are sensitive to equipment operating conditions and its surroundings, the measurement of total radiated power is considered to be a significant parameter related to disturbance control. It can be measured by placing the equipment in a suitable chamber with metal walls. To avoid effects of standing waves that would otherwise produce non-uniform distribution of energy density with position in the chamber, rotating stirrers are installed. With proper size, shape and position, the energy density at any position in the chamber varies randomly with a constant statistical distribution law in phase, amplitude and polarization.

17.1 *Chamber*

17.1.1 *Size and shape*

The linear dimensions of the chamber shall be large relative to the wavelength of the lowest frequency of interest. It shall also be large enough to accommodate the equipment under test, the stirrers and the measuring antennas. Microwave equipment varies in size from the small table top oven having a volume of about 0,2 m^3 to large units 1,7 m high with a 760 mm base. The chamber may be of any shape provided its three dimensions are of the same order. The three dimensions should preferably be different. For a lowest frequency of 1 GHz, the chamber shall have a volume at least 8 m^3. The actual dimensions will depend on the physical characteristics of the chamber. See 17.1.4 for method of test of the suitability of the chamber.

The walls and the stirrers shall be metallic. Joints between the metallic members shall be mechanically sound and of low electrical resistance along the whole length, and there shall be no surface corrosion. No absorbing material, such as wood, shall be placed inside the chamber.

17.1.2 *Door, openings in walls, and mounting brackets*

The enclosure door shall be large enough to allow the passage of operators and equipment. It shall open outward, and fit tightly to minimize energy losses. For convenience in mounting, transmitting and receiving antennas inside the chamber, mounting brackets may be fixed to the walls.

17.1.3 *Stirrers*

The following describes two examples of stirrers. Other shapes are permissible provided stirring efficiency meets the criteria in 17.1.4.

17.1.3.1 *Rotating vanes*

If rotating vanes are used, two vanes are placed on adjacent walls of the chamber spaced at least 1/4 of the maximum wavelength used from the walls and of sufficient thickness to be rigid. They shall be of the maximum length allowed by the wall sizes and their width shall be about 1/5 of the length.

17.1.3.2 *Rotating paddles*

If rotating paddles are used, two or three paddles are mounted on the walls of the chamber. The paddles shall be mutually at right angles. The paddles may be of the shape shown in figure 18 and rotate about an axis parallel to their length. The diameter of the swept tubular space shall be at least equal to the maximum wavelength used, and the lengths shall be the maximum allowed by the wall sizes. The structure shall be rigid.

17.1.3.3 *Rotating speed*

The rotation speeds of the stirrers shall be different. The longest time for one rotation of the stirrers shall be less than 1/5 of the integrating time of the measuring instrument. For the measuring equipment described in 17.1.5, a suitable rate is between 50 rev/min and 200 rev/min. The motors used to rotate the stirrers, together with their reduction gear, should preferably be outside the walls of the chamber.

17.1.4 *Test for the efficiency of the stirrers*

The desired uniform distribution of energy in the chamber is shown by the smoothness of the variation with frequency of coupling attenuation (described in 17.1.5). At low frequencies, due to the longer wavelengths, it is more difficult to achieve this uniformity and there exist pronounced maxima and minima. The greater the efficiency of the stirrers the smaller are these maxima and minima and hence the usable frequency is lower.

The coupling attenuation is measured over the usable frequency range of the chamber. At the lower frequencies where the maxima and minima are observable, values shall be measured at about 100 MHz intervals. The receiving antenna then remains fixed, the transmitting antenna is rotated at 45-degree intervals and the test is repeated for each position and at each frequency. The whole test shall be repeated again with the receiving antenna rotated at 90 degrees. The stirrers are considered satisfactory when: (1) the envelope of the graph of the maxima and the minima does not exceed 2 dB in any position of the transmitting antenna, and, (2) the means of the four graphs are within an envelope of 2 dB or less. Figure 19 shows a typical result.

17.1.5 *Coupling attenuation*

The coupling attenuation of a chamber is the insertion loss measured between the terminals of the transmitting and the receiving antennas in the chamber. A calibrated signal generator whose power output can be accurately measured is used to feed power to a low-loss transmitting antenna (e.g. a horn antenna) located inside the chamber or on a chamber wall. A receiving antenna may be placed at any point in the chamber provided it is at least 1/4 wavelength from the walls and not pointing toward the transmitting antenna, towards the nearest chamber wall, or aligned with any of the chamber axis.

A low-noise RF amplifier is connected to the receiving antenna via a high-pass filter; its output is connected through a band-pass filter to a diode detector. The band-pass filter shall be tuned to the frequency of interest and be of the specified bandwidth. The output of the detector is connected to a peak reading voltmeter with a specified peak-hold time (the hold time will depend on the equipment being measured). A spectrum analyzer may also be used for this measurement. The power absorbed by the transmitting antenna, P, is noted. The signal generator is then connected to the input of the low-noise amplifier, and its power output, p, is adjusted to give the same voltmeter reading. The power absorbed by the low-noise amplifier is noted. The coupling attenuation is 10 lg (P/p) dB.

18 Coupling units for conducted current immunity measurement

The coupling units are designed to inject the disturbance current on to the leads under test and to isolate the other leads and any apparatus which is connected to the equipment under test from the effects of these currents. With a 150 Ω source impedance, there is a useful correlation between the RF disturbance field strength acting on a real installation and the e.m.f. that must be applied in the current injection method to produce the same degree of impairment, at least for frequencies up to 30 MHz. The immunity of an apparatus is expressed by this e.m.f. value. Annexes N and P give the principle of operation and examples of types of units and their construction.

18.1 *Characteristics*

The performance checks of the coupling units are done on the impedance in the frequency range 0,15 MHz to 30 MHz and on insertion loss in the frequency range 30 MHz to 150 MHz.

18.1.1 *Impedance*

In the frequency range 0,15 MHz to 30 MHz, the total asymmetric impedance (RF choke coil in parallel with the 150 Ω resistive disturbance source impedance) measured between the point of injection of the disturbance signal to the equipment under test and the ground of the unit shall have a modulus of 150 Ω ± 20 Ω and a phase angle less than ±20° (this impedance is the same as the CISPR 150 Ω artificial mains V-network, see 11.4).

For example, for coupling units type A and S, the point of injection is the shield of the output connector; for types M and L, the point of injection is the joint output terminals.

18.1.2 *Insertion loss*

In the frequency range 30 MHz to 150 MHz the insertion loss of two identical coupling units in tandem shall be within the range 9,6 dB to 12,6 dB, measured as shown in figure 20.

19 TEM cells for immunity to radiated disturbance measurement
(under consideration)

20 Measuring networks for telecommunication lines
(under consideration)

Annex A
(normative)

Determination of response to repeated pulses of quasi-peak and r.m.s. measuring receivers
(subclauses 1.3.2, 2.4.2, 5.2.2 and 5.4.1)

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 −6dB 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:

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

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:

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

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

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

where:

$\omega = 2\pi f$.

The bandwidths B_3 and B_6 will be:

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

$$B_6 = \sqrt{2} \times \omega_0/\pi = 0{,}450\ \omega_0 \tag{3b}$$

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:

$$\Delta f = (1/F_0^{\,2}) \int_{-\infty}^{+\infty} F^2(f)\, df \tag{4}$$

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 $F_0 = 1$

$$\Delta f = \int_{-\infty}^{+\infty} F^2(f)\, df \tag{5}$$

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

$$\Delta f = \int_{0}^{+\infty} 2\left[2\omega_0^{\,2}/(\omega_0 + j\omega)^2 + \omega_0^{\,2}\right]^4 df \tag{6}$$

this leads to:

$$\Delta f = 0{,}265\ \sqrt{2} \times \omega_0 = 0{,}375\ \omega_0 \tag{7}$$

thus:

$$B_3 = 0{,}963\ \Delta f \tag{8}$$

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:

$$\mathrm{d}U/\mathrm{d}t + U/(RC) = A\,(\sin\theta - \theta\cos\theta)/(\pi \times SC) \qquad (9)$$

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 (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 (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:

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

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:

$$U_{rms} = \left[n \int_{0}^{+\infty} (A^2(t)/2)dt \right]^{1/2} \qquad (11)$$

where

n is the pulse repetition frequency in hertz.

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

$$U_{rms} = \left[n \int_{-\infty}^{+\infty} (2\upsilon\tau \times F^2(f)/2)df \right]^{1/2} \qquad (12)$$

where

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

This gives:

$$U_{rms} = \sqrt{2} \times \upsilon\tau \times \sqrt{n} \left[\int_{-\infty}^{+\infty} F^2(f)df \right]^{1/2} \qquad (13)$$

Which, from equation (5), gives:

$$U_{rms} = \sqrt{2} \times \upsilon\tau \times \sqrt{n} \sqrt{\Delta f} \qquad (14)$$

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

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

thus:

$$\upsilon\tau = (100 \sqrt{2}) / \sqrt{\Delta f} \qquad (\mu V s) \qquad (15)$$

or from equation (8):

$$\upsilon\tau = 139 / \sqrt{B_3} \qquad (\mu Vs) \qquad (16)$$

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 (14):

$$U_{rms} = (\upsilon\tau) \times (2n \, \Delta f)^{1/2}$$

from equation (1), and for $G = 1$:

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

thus overload factor:

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

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 (16):

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

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

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

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 (2) and a bandwidth at 6 dB equal to the nominal bandwidths prescribed in section 1, the following relationships for $(\upsilon\tau)_{rms}/(\upsilon\tau)_{qp}$ exist:

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

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

for the frequency range 30 MHz to 1 000 MHz:

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

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 2.4, 3.4, 4.4, 5.4)

B.1 Pulse generator

For checking compliance with the requirements of section 1 of this standard, a pulse generator is needed. Compliance with the requirements of 2.4, 2.6, 3.4, 4.4, and 5.4 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 2.6, 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 2.4, 3.4, 4.4, 5.4)

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.

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

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 2.4.1, 3.4, 4.4.1 and 5.4.1, 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 2.4.2, 3.4, 4.4.2 and 5.4.2 the impulse area shall not depend on their repetition frequency.

C.2.4 For determining compliance with 2.4, 3.4, 4.4 and 5.4 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 upon its pulse response
(subclause 2.4.2)

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 4.2.1)

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:

$$\int_{-\infty}^{+\infty} A(t)\mathrm{d}t = 2\upsilon\tau G_0$$

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.

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 (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:

$$B_{imp} = A(t)_{max} / 2G_0$$

where

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

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* *"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 (17) (annex A), we have:

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

where

B_6 and B_3 are defined in 1.1.

For other types of tuned circuits, the ratio of B_{imp} to B_6 may be estimated from figure 21 if the ratio of B_{20} to B_3 is known, where B_{20} is the bandwidth at 20 dB.

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 Section 1. 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 22, 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:

$$R_C/R_D = (1/4)\ (T_C/T_D)$$

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:

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

From the 6 dB bandwidths specified in table 1 (2.2), 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 2.4.1) 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)

Annex F
(normative)

Artificial mains networks
(clause 11)

This annex sets forth information and data concerning artificial mains networks used in the measurement of radio-frequency (RF) voltages over the frequency range 9 kHz to 100 MHz and having current carrying capabilities of up to 500 A. Included are V-networks for voltage measurements between each conductor of the supply mains and reference earth, and delta-networks for voltage measurements between conductors of the supply mains (symmetrical) and between the mid-point of the conductors of the supply mains and reference earth (asymmetrical).

F.1 General

An artificial mains network circuit has to provide firstly the specified impedance over the working frequency range. It has to provide sufficient isolation to spurious signals in the mains supply (the spurious signals generally should be at least 10 dB below the measurement level at the measuring receiver). Also it has to prevent the mains voltage from being applied to the measuring receiver. It should have these provisions for each conductor of the mains (two-wire in single-phase and four-wire in three-phase), a switch to connect the measuring receiver to the mains conductor under measurement and to provide the correct termination to the other mains conductors. The circuits given in the following have these facilities. They are given for the case of two-wire single-phase mains. The extension to four-wire three-phase use is simply done.

F.2 An example of the 50 Ω/50 μH + 5 Ω artificial mains V-network

Figure 23 shows a suitable circuit with the component values listed in table F.1. L1, C1, R1, R4 and R5 define the impedance; L2, C2 and R2 provide the isolation to spurious mains signals and mains impedance variations, and C3 decouples the measuring receiver from mains voltage. It may be constructed for use with currents up to 100 A.

Table F.1 – Component values of 50 Ω/50 μH + 5 Ω network

Component	Value
R1	5 Ω
R2	10 Ω
R3	1 000 Ω
R4	50 Ω
R5	50 Ω (input impedance of the measuring receiver)
C1	8 μF
C2	4 μF
C3	0,25 μF
L1	50 μH
L2	250 μH

At the lowest frequencies of the range 9 kHz to 150 kHz, the 0,25 µF capacitance of C3 does not have a negligible impedance. Unless otherwise specified, it will be necessary to make a correction for this impedance.

Since C1 and C2 have high capacitances, for safety reasons the network case should either be solidly bonded to reference earth or a mains isolating transformer should be used.

The inductance L2 should have a Q-factor not less than 10 over the 9 KHz to 150 kHz frequency range. In practice, it is advantageous to use inductors coupled in series opposition in the live and neutral lines (common-core choke).

Clause F.7 describes a suitable construction for the inductor L1. For equipment requiring currents greater than 25 A, difficulties may be encountered in the construction of L2. In this case the isolating section L2, C2 and R2 may be omitted. The effects will be that the impedance of the network at frequencies below 150 kHz may be outside the tolerance specified in 11.2, and the isolation of mains noise may not be sufficient.

This circuit may also satisfy the requirements of the 50 Ω/50 µH artificial mains V-network specified in 11.3.

F.3 An example of the 50 Ω/50 µH artificial mains V-network

Figure 24 shows the circuit with the components values as listed in the table F.2. L1, C1, R2, R3 and R4 define the impedance. Unlike the previous example, there is no isolating section since the circuit is able to meet the impedance specification. However, in cases of high ambient mains noise a filter is required to reduce the spurious signal level. This network may be constructed for use with currents up to 100 A.

Table F.2 – Component values of 50 Ω/50 µH network

Component	Value
R1	1 000 Ω
R2	50 Ω
R3	0 Ω
R4	50 Ω (input impedance of the measuring receiver)
R5	0 Ω
C1	1 µF
C2	0,1 µF
L1	50 µH

Since C1 has a high capacitance, for safety reasons the network case shall either be solidly bonded to reference earth or a mains isolating transformer shall be used.

Clause F.7 describes a suitable construction for the inductor L1.

F.4 Examples of the 50 Ω/5 µH + 1 Ω artificial mains V-network

The circuit of figure 24 with the component values given in the table F.3 is suitable for frequencies 150 kHz to 30 MHz, and currents up to 400 A.

Table F.3 – Component values of 50 Ω/5 µH + 1Ω network

Component	Value
R1	1 000 Ω
R2	50 Ω
R3	0 Ω
R4	50 Ω (input impedance of the measuring receiver)
R5	1 Ω
C1	2 µF (minimum)
C2	0,1 µF
L1	5 µH

An alternative circuit with component values is shown in figure 25. It is suitable for the frequency range 150 kHz to 100 MHz, and for currents up to 500 A.

F.5 An example of the 150 Ω artificial mains V-network

Figure 24 shows a suitable circuit. The component values are given in table F.4.

Table F.4 – Component values of the 150 Ω V-network

Component	Value
R1	1 000 Ω
R2	150 Ω
R3	100 Ω
R4	50 Ω (input impedance of the measuring receiver)
R5	0 Ω
C1	1 µF
C2	0,1 µF
L1	suitable value to achieve the specified impedance

F.6 Example of the 150 Ω artificial mains delta-network

Figure 26 shows a suitable circuit. The component values are given in table F.5.

Table F.5 – Component values of the 150 Ω delta-network

Components	Values
R1, R2	118,7 (120) Ω
R3, R5	152,9 (150) Ω
R4	390,7 (390) Ω
R6, R7	275,7 (270) Ω
R8, R9	22,8 (22) Ω
R10, R11	107,8 (110) Ω
R12	50 Ω
C1, C2	0,1 μF
L, C	suitable values to achieve the specified impedance

NOTES

1 The turns ratio of the balanced to unbalanced transformer is assumed to be 1:2,5 with center tap.

2 Resistance values shown in brackets are the nearest preferred values (±5 % tolerance).

Calculations give the following network performance. Values in brackets are based on the resistance values in brackets.

Attenuation:	Symmetrical	20 (20) dB
	Asymmetrical	20 (19,9) dB
Network impedance:	Symmetrical	150 (150) Ω
	Asymmetrical	150 (148) Ω

F.7 An example of a design for an artifical mains network with a 50 μH inductor

F.7.1 *The inductor*

The solenoidal winding of the inductor shown in figure 27 consists of 35 turns of a single layer of 6 mm diameter copper wire with an 8 mm pitch wound on a coil former of an insulating material. Its inductance is greater than 50 μH outside the metal case and 50 μH inside the metal case.

The diameter of the inductor is 130 mm. In order to improve the electrodynamic stability of the winding, a 3 mm deep spiral groove is made in the coil former, and the wire is laid in this groove.

The higher frequency characteristics of the inductor are improved by sectionalizing the winding. Alternate sections, each of 4 turns, are each shunted by a 430 Ω resistor. These act to suppress internal resonances in the inductor, which otherwise would cause the input impedance to deviate from the specified value at certain frequencies.

F.7.2 *The case of the inductor*

The inductor and the other components of the network are mounted on a metal frame which is then closed by metal lids. The bottom and side lids are perforated in order to improve the heat dissipation. The dimensions of the case are 360 x 300 x 180 mm. Figure 28 shows a general view.

NOTE - It is recommended that the load-end terminals of the network be located as near as possible to a corner of that end of the case, so that two or more networks may be assembled with short leads from these terminals to the socket to be used for attachment of the equipment under test.

F.7.3 *Isolation of the inductor*

Figure 29 shows the attenuation to signals on the mains supply when the inductor is used in the circuit of figure 23 but without the isolation section L2, C2, and R2. The attenuation is determined as that between the supply mains terminal and the radio disturbance measuring apparatus terminal. In the case of curve 1, the internal impedance of the signal generator at the mains terminal is 50 Ω resistive. In curve 2, the internal impedance of the generator is varied in accordance with the nominal value of the magnitude of input impedance of the artificial mains network as given in figure 29.

Annex G
(normative)

Validation procedure of the open area test site for the frequency range of 30 MHz to 1 000 MHz
(clause 16)

G.1 General

Subclause 16.6 contains the general requirements and procedures for determining site validation using normalized site attenuation measurements. This annex provides step-by-step procedures to perform the NSA measurements.

G.2 Discrete frequency method

G.2.1 *Measurement set-up*

Refer to figures 16 and 17 for specific test set-up details. The signal generator is connected to the transmit antenna with an appropriate length of transmission line. The transmit antenna is placed in the desired location. The transmit antenna height is set to h_1 (see tables G.1, G.2 and G.3 for the values of h_1) and the desired polarization is selected. If a tunable dipole is used, the length is adjusted for the required frequency.

The receive antenna is mounted on a mast which allows scanning over the height range $h_2$min to $h_2$max, placed at a distance R from the transmit antenna, and connected to the measuring receiver or spectrum analyzer via a suitable length of cable. The same polarization as that for the transmit antenna is selected and, if a tunable dipole is used, the antenna is adjusted to the required frequency. The 25 cm ground clearance is maintained for vertically oriented tuned dipoles (see table G.3).

For all NSA measurements using tunable dipoles, it is assumed that these antennas are tuned to each frequency, including those between 30 MHz and 80 MHz.

G.2.2 *Measurement procedure*

The following steps should be used for each frequency indicated in tables G.1, G.2, and G.3. The measurements are first made for antennas horizontally aligned and then for antennas vertically aligned with the transmit antenna height set at h_1.

1) Adjust the output level of the signal generator to give a received voltage display well above ambient and measuring receiver or spectrum analyzer noise.

2) Raise the receiving antenna on the mast through scan h_2 as indicated in tables G.1, G.2 and G.3, as appropriate.

3) Record the maximum signal level. This value is V_{SITE} in equation (1), in 16.6.1.

4) Disconnect the transmit and receive cables from their antennas. Directly connect these cables with a straight through adapter.

5) Record the signal level with the transmit and receive cables connected. This value is V_{DIRECT} in equation (1), in 16.6.1.

6) At each frequency and for each polarization, enter the values in steps 3 and 5 in equation (1), in 16.6.1.

7) Insert the transmit and receive antenna factors at the measurement frequency as shown in equation (1).

8) Insert the mutual impedance correction factor ΔAF_{TOT} from table G.4 which applies only for the specific geometry of horizontal polarization using tunable dipoles separated by 3 m. $\Delta AF_{TOT} = 0$ for all other geometries.

9) Solve equation (1) for A_N which is the NSA for the measurement frequency and polarization used.

10) Subtract the value in step 9 from the appropriate NSA contained in tables G.1, G.2 and G.3, as appropriate.

11) If the results in step 10 are less then ±4 dB, the site is considered validated at that frequency and polarization.

12) Repeat steps 1 through 11 for the next frequency and polarization combination.

G.3 Swept frequency method

G.3.1 *Measurement set-up*

The set-up is similar to that contained in G.2.1 except that only broadband antennas are used. No restrictions in vertical polarization antenna movement is necessary due to the physically small size of such broadband antennas.

G.3.2 *Measurement procedure*

The following steps should be made using automatic measuring equipment having a peak hold (max. hold), storage capability, and tracking generator. In this method, both receive antenna height h_2 and frequency are scanned or swept over the required frequency ranges. The frequency ranges are usually determined by the type of broadband antenna used. The frequency sweep speed shall be much greater than the antenna height scan rate. Set the transmit antenna height to h_1.

1) Adjust the output level of the tracking generator to give a received voltage display well above ambient scanning receiver or spectrum analyzer noise.

2) Raise the receiving antenna on the mast to the maximum height of the scan range as indicated in the appropriate table G.1.

3) Set the spectrum analyzer to sweep the desired frequency range. Ensure that the spectrum analyzer is adjusted so that a similar signal up to 60 dB higher can be displayed on the same amplitude scale. This will accommodate the levels to be recorded in step 5.

4) Slowly lower the receiving antenna to the minimum height of the scan range as indicated in the tables for the appropriate site geometry. Store or record the maximum received voltage display V_R in dB(µV). (The time it takes to lower the antenna should be much longer than the spectrum analyzer sweep time.)

5) Disconnect the transmit and receive cables and connect them directly with a straight through adapter. Store or record the resulting voltage display.

6) At each frequency, subtract the voltage measured in step 4 from the voltage measured in step 5. Also subtract the antenna factors of the transmit and receive antennas, AF_T(dB/m) and AF_R(dB/m), respectively. (Antenna factors as a continuous function of frequency can be obtained by using simple linear curve fitting on a set of discrete antenna factor values.) The result is the measured NSA over the range of frequencies used, which should be plotted. Also plot the theoretical normalized site attenuation for an ideal site shown in table G.1.

7) The differences found between the theoretical NSA and the measured NSA shall fall within the ±4 dB criterion.

NOTE - For both NSA measurement methods, an impedance mismatch in the output of the signal source or at the input of the measuring receiver or spectrum analyzer may result in reflections which could cause errors. This should be avoided by use of padding attenuators of 10 dB; one at the output end of each transmitting and receiving antenna cable. These attenuators shall remain in the cables during the entire measurement for NSA.

G.4 Possible causes for exceeding site acceptability limits

If the deviation exceeds the ±4 dB criterion, investigate as follows:

First check the measurement system calibrations. If the signal generator and measuring instrumentation do not drift during the measurements, the prime suspects are the antenna factors. Antennas may also be defective. If these all check out, repeat the measurement. If the differences are still greater than ±4 dB, the site and the surrounding area are suspect. The vertical site attenuation should in general be the most sensitive to site anomalies. If so, use that measurement as the basis for tracking down the problem. Possible problems include inadequate ground plane construction and size, reflecting objects too close by (fences, buildings, light towers, etc.), degraded performance of all-weather enclosures due to inadequate construction and maintenance techniques, and such long-term effects as penetration of residue from airborne conductive contaminants.

G.5 Antenna calibration

The antenna factors of broadband antennas used to make site attenuation measurements should be traceable to a national standard*. Manufacturer's antenna factors may not be sufficiently accurate to achieve good agreement between measured and calculated normalized site attenuations. Antenna factors usually account for losses due to the balun.

* A calibration procedure is under consideration.

If a separate balun is used, its effects shall be accounted for. Experience has shown that variations of antenna factors with geometry and polarization are generally negligible for the types of broadband antennas commonly used for EMC measurements below 1 GHz (e.g., biconicals, thick dipoles and log-periodics) as long as the transmit antenna is at least 1 m above the ground plane. If antenna factor variations are suspected because of the use of unusual antennas or measurement geometries, or from effects such as mutual coupling, or transmission line scattering for vertically polarized antennas, especially at the 3-m measurement distance, the antenna factors should first be measured using these geometries.

Normally the site attenuation is measured in a 50 Ω system, i.e. the signal generator and measuring receiver have an impedance of 50 Ω and the radiation impedances of the transmitting and receiving antennas are balanced and matched via a balun.

Manufacturer's antenna factors are normally also specified for an impedance of 50 Ω, i.e. the conversion factor for a without loss matching of the 50 Ω impedance to the radiation impedance of the antenna and, if applicable, the loss of the used balun is also contained in the given antenna factor.

If tuned half-wave dipoles are used, their free-space antenna factors can be calculated, using the following equation:

$$AF = 20 \lg (2\pi/\lambda) + 10 \lg (73/50) \text{ (dB)} \quad (1)$$

$$= 20 \lg f - 31{,}9 \text{ dB} \quad (2)$$

where

f is in MHz.

NOTE - In practice, the antenna factor will be affected by the height of the dipole antenna above ground because of the mutual impedance of the dipole and its image in the ground.

The average balun loss for a well designed tuned half-wave dipole is approximately 0,5 dB. Hence equation (2) becomes

$$AF = 20 \lg f - 31{,}4 \text{ (dB)} \quad (3)$$

This balun loss should be measured by connecting transmit and receive dipole back to back before they are installed in their housings. The loss per balun is 1/2 of the total loss measured, assuming both baluns are equal.

It is important to check that these calculated values are representative of the values for the particular tuned dipoles used for the NSA measurements. The simplest check is to measure the VSWR with the antennas assembled and its elements tuned to resonance. The antenna shall be placed at least 4 m above the ground, higher if possible, to minimize antenna to ground coupling, and its elements tuned to resonance using the measurements shown in table G.3. It is sufficient to check the VSWR of the antennas at frequencies in the low end, middle and high end of their frequency ranges.

Below 100 MHz, the function of the baluns may also be checked by removing the elements, placing a 70 Ω resistor across the terminals of the element mounting block, and measuring the VSWR of the terminated balun. The VSWR should be less than 1,5 to 1.

Table G.1 – Normalized site attenuation*

(Recommended geometries for broadband antennas)

Polarization	Horizontal	Horizontal	Horizontal	Horizontal	Vertical	Vertical	Vertical	Vertical
R (m)	3	10	30	30	3	10	30	30
h_1 (m)	1	1	1	1	1	1	1	1
h_2 (m)	1 to 4	1 to 4	2 to 6	1 to 4	1 to 4	1 to 4	2 to 6	1 to 4
f_m (MHz)	A_N (dB)							
30	15,8	29,8	44,4	47,8	8,2	16,7	26,1	26,0
35	13,4	27,1	41,7	45,1	6,9	15,4	24,7	24,7
40	11,3	24,9	39,4	42,8	5,8	14,2	23,6	23,5
45	9,4	22,9	37,3	40,8	4,9	13,2	22,5	22,5
50	7,8	21,1	35,5	38,9	4,0	12,3	21,6	21,6
60	5,0	18,0	32,4	35,8	2,6	10,7	20,1	20
70	2,8	15,5	29,7	33,1	1,5	9,4	18,7	18,7
80	0,9	13,3	27,5	30,8	0,6	8,3	17,6	17,5
90	–0,7	11,4	25,5	28,8	–0,1	7,3	16,6	16,5
100	–2,0	9,7	23,7	27	–0,7	6,4	15,7	15,6
120	–4,2	7,0	20,6	23,9	–1,5	4,9	14,1	14,0
140	–6,0	4,8	18,1	21,2	–1,8	3,7	12,8	12,7
160	–7,4	3,1	15,9	19	–1,7	2,6	11,7	11,5
180	–8,6	1,7	14,0	17	–1,3	1,8	10,8	10,5
200	–9,6	0,6	12,4	15,3	–3,6	1,0	9,9	9,6
250	–11,9	–1,6	9,1	11,6	–7,7	–0,5	8,2	7,7
300	–12,8	–3,3	6,7	8,8	–10,5	–1,5	6,8	6,2
400	–14,8	–5,9	3,6	4,6	–14,0	–4,1	5,0	3,9
500	–17,3	–7,9	1,7	1,8	–16,4	–6,7	3,9	2,1
600	–19,1	–9,5	0	0	–16,3	–8,7	2,7	0,8
700	–20,6	–10,8	–1,3	–1,3	–18,4	–10,2	–0,5	–0,3
800	–21,3	–12,0	–2,5	–2,5	–20,0	–11,5	–2,1	–1,1
900	–22,5	–12,8	–3,5	–3,5	–21,3	–12,6	–3,2	–1,7
1 000	–23,5	–13,8	–4,5	–4,4	–22,4	–13,6	–4,2	–3,5

* These data apply to antennas that have at least 25 cm of ground plane clearance when the centre of the antennas is 1 m above the ground plane in vertical polarization.

Table G.2 – Normalized site attenuation

(Recommended geometries for tuned half-wave dipoles, horizontal polarization)

Polarization	Horizontal	Horizontal	Horizontal
R (m)	3**	10	30
h_1 (m)	2	2	2
h_2 (m)	1 to 4	1 to 4	2 to 6
f_m (MHz)	A_N (dB)		
30	11,0	24,1	38,4
35	8,8	21,6	35,8
40	7,0	19,4	33,5
45	5,5	17,5	31,5
50	4,2	15,9	29,7
60	2,2	13,1	26,7
70	0,6	10,9	24,1
80	–0,7	9,2	21,9
90	–1,8	7,8	20,1
100	–2,8	6,7	18,4
120	–4,4	5,0	15,7
140	–5,8	3,5	13,6
160	–6,7	2,3	11,9
180	–7,2	1,2	10,6
200	–8,4	0,3	9,7
250	–10,6	–1,7	7,7
300	–12,3	–3,3	6,1
400	–14,9	–5,8	3,5
500	–16,7	–7,6	1,6
600	–18,3	–9,3	0
700	–19,7	–10,6	–1,3
800	–20,8	–11,8	–2,4
900	–21,8	–12,9	–3,5
1 000	–22,7	–13,8	–4,4

** The mutual impedance correction factors (see table G.4) for horizontally polarized tuned half-wave dipoles spaced 3 m apart should be subtracted from the measured normalized site attenuation data for comparison with the theoretical normalized site attenuation values for an ideal site given in this table.

Table G.3 – Normalized site attenuation

(Recommended geometries for tuned half-wave dipoles – vertical polarization)

f_m MHz	R = 3 m, h_1 = 2,75 m		R = 10 m, h_1 = 2,75 m		R = 30 m, h_1 = 2,75 m	
	h_2 (m)	A_N (dB)	h_2 (m)	A_N (dB)	h_2 (m)	A_N (dB)
30	2,75 to 4	12,4	2,75 to 4	18,8	2,75 to 6	26,3
35	2,39 to 4	11,3	2,39 to 4	17,4	2,39 to 6	24,9
40	2,13 to 4	10,4	2,13 to 4	16,2	2,13 to 6	23,8
45	1,92 to 4	9,5	1,92 to 4	15,1	2 to 6	22,8
50	1,75 to 4	8,4	1,75 to 4	14,2	2 to 6	21,9
60	1,50 to 4	6,3	1,50 to 4	12,6	2 to 6	20,4
70	1,32 to 4	4,4	1,32 to 4	11,3	2 to 6	19,1
80	1,19 to 4	2,8	1,19 to 4	10,2	2 to 6	18,0
90	1,08 to 4	1,5	1,08 to 4	9,2	2 to 6	17,1
100	1 to 4	0,6	1 to 4	8,4	2 to 6	16,3
120	1 to 4	–0,7	1 to 4	7,5	2 to 6	15,0
140	1 to 4	–1,5	1 to 4	5,5	2 to 6	14,1
160	1 to 4	–3,1	1 to 4	3,9	2 to 6	13,3
180	1 to 4	–4,5	1 to 4	2,7	2 to 6	12,8
200	1 to 4	–5,4	1 to 4	1,6	2 to 6	12,5
250	1 to 4	–7,0	1 to 4	–0,6	2 to 6	8,6
300	1 to 4	–8,9	1 to 4	–2,3	2 to 6	6,5
400	1 to 4	–11,4	1 to 4	–4,9	2 to 6	3,8
500	1 to 4	–13,4	1 to 4	–6,9	2 to 6	1,8
600	1 to 4	–14,9	1 to 4	–8,4	2 to 6	0,2
700	1 to 4	–16,3	1 to 4	–9,7	2 to 6	–1,0
800	1 to 4	–17,4	1 to 4	–10,9	2 to 6	–2,4
900	1 to 4	–18,5	1 to 4	–12,0	2 to 6	–3,3
1 000	1 to 4	–19,4	1 to 4	–13,0	2 to 6	–4,2

Table G.4 – Mutual impedance correction factors

(For horizontally polarized tuned half-wave dipoles spaced 3 m apart)

ΔAF_{TOT} – Antenna factor correction in dB Geometry: R = 3 m, h_1 = 2 m, h_2 = 1 to 4 m	
f_m (MHz)	Pair of resonant dipoles
30	3,1
35	4,0
40	4,1
45	3,3
50	2,8
60	1,0
70	–0,4
80	–1,0
90	–1,0
100	–1,2
120	–0,4
125	–0,2
140	–0,1
150	–0,9
160	–1,5
175	–1,8
180	–1,0
200	0,1

Annex H
(normative)

Calibration of the absorbing clamp
(clause 13)

Connect and arrange the clamp as shown in figure 40. Lead W consists of an insulated wire of 1 mm or 2 mm effective cross-section connected to the centre pin of a 50 Ω connector mounted on a metal screen such that only the centre pin protrudes from the screen. The screen may be the outer surface of a screened enclosure or a large metal sheet, say 2,5 m by 2,5 m. Lead W shall be centralized within the current transformer as shown in figure 40.

If the RF isolation provided by an actual absorbing clamp is insufficient at lower frequencies, particularly below 50 MHz and especially during calibration, a second absorber should be placed around the lead behind the absorbing clamp under calibration. It may be in a fixed position about 4 m from the starting of the lead.

Connect a generator with a 50 Ω resistive output impedance to the other end of the connector through a 50 Ω, 10 dB attenuator, and a measuring receiver having a 50 Ω resistive input impedance to the RF terminal of the clamp. The coaxial cable from the clamp to the receiver shall have ferrite absorbing rings or sleeves fitted around both ends.

The calibration is a measurement of the insertion loss of the absorbing clamp and calibration wire set-up between the coaxial connectors C1 and C2. With the coaxial cables in positions a and b as shown by the solid lines in figure 40 the absorbing clamp is moved along the wire from the metal screen up to a distance of a half-wavelength at the frequency of calibration: and the maximum indication I on the measuring receiver is noted. With the generator signal level kept constant, the coaxial cables are connected in positions a′ and b′ as shown by the dotted lines in figure 40 and the receiver indication I′ is noted. The insertion loss L is given by $L = I' - I$ (dB). This is done throughout the desired frequency range.

An example of the calibration results is shown in figure 41. The measured insertion loss normally lies within the range 14 dB to 22 dB.

The measuring receivers specified in this standard have an input impedance of 50 Ω. For such an impedance it can be shown that:

if P is the input power, and V is the input voltage,

$$10 \lg P = 10 \lg (V^2/50) = 20 \lg V - 10 \lg 50 = (20 \lg V) - 17$$

If the power, P, is expressed in picowatts, the equivalent voltage, V, is in microvolts. The numerical value of P, expressed in dB can be found by subtracting 17 dB from the numerical value of V in dB. Thus, if 17 dB is subtracted from the insertion loss the remainder may be added to the meter reading in dB(µV) to give directly the disturbance power in dB(pW). This is the reason for the correction scale shown in figure 41. The correction scale gives the factor in dB to be added to the indication of the measuring receiver in dB(µV) to convert to power dB(pW).

It is normally possible to position the clamp at more than one maximum. The maximum nearest the end of the conductor that is attached to the 50 Ω connector gives the maximum reading on the receiver. It has been found in practice that the second maximum gives an insertion loss which is about 1 dB greater than that obtained with the first maximum.

For some practical applications it is convenient to use the second maximum, and thus it is useful to calibrate the clamp for this. An example of a calibration employing the second maximum is shown in figure 42, curve B.

Annex J
(Informative)

Construction, frequency range, and calibration of current probes
(clause 12)

J.1 Physical and electrical considerations for current probes

The physical size of the current probe is a function of the maximum cable size to be measured, the maximum power current flowing in the cable, and the range of signal frequencies to be measured.

The current probe is usually of toroidal shape with the conductor to be measured placed within the centre opening of the toroid. Existing requirements and manufacturers' specifications show that the centre opening may vary from 2 mm to 30 cm in diameter. The secondary winding is placed on the toroid in such a manner as to facilitate the clamp-on function of the probe. The toroidal core and winding is enclosed with a shield to prevent electrostatic pick-up. The shield has a gap to prevent it from being a shorted turn on the transformer.

Typical current probes for disturbance measurements use seven to eight secondary turns. This number of turns is an optimized turns-ratio to ensure a maximized flat frequency range and an insertion impedance of 1 Ω or less. For frequencies below 100 kHz laminated silicon steel cores are used. Ferrite cores are used between 100 kHz to 400 MHz and air cores are used between 200 MHz to 1 000 MHz with a balanced coil to unbalanced 50 Ω output transformer. Figure 30 shows the configuration of a typical current probe.

The current probe is generally used as a pick-up device for disturbance measurements. Therefore, it is designed to transfer the disturbance current to a voltage which can be detected by the meter. The sensitivity of the current probe may be expressed conveniently in terms of transfer impedance. Transfer impedance is defined as the ratio of secondary voltage (generally across a 50 Ω resistive load) to the primary current. The transfer admittance is sometimes used instead.

Overall sensitivity of the current probe and disturbance receiver is also a function of the receiver sensitivity. Minimum detectable disturbance current in a conductor is the ratio of receiver sensitivity (V) to current probe transfer impedance (Ω). For instance, if a one microvolt (1 μV) receiver and a current probe with a transfer impedance of 10 Ω are used, then the minimum measurable disturbance current is 0,1 μA. However, if a 10 μV receiver and a current probe with a transfer impedance of 1 Ω are used, then the minimum measurable current is 10 μA. To obtain maximum sensitivity, the transfer impedance should be as high as possible.

The transfer impedance Z_T is often expressed in terms of decibels (dB) above 1 Ω. This is a convenient unit in reference to the more general disturbance units of decibels above 1 µV or 1 µA (Z_T in terms of decibels above one Ω is taken as 20 log Z_T).

J.2 Equivalent electrical circuit of current probe

The current probe may be represented by an exact equivalent circuit from general transformer theory. It is not necessary to repeat the circuit here since it is shown in many standard textbooks*. After considerable simplification of the exact circuit and derived equations, the following equations for the transfer impedance result:

High-frequency case: $$Z_T = \frac{\omega M}{\left[(\omega L/R_L)^2 + (\omega^2 LC - 1)^2\right]^{1/2}}$$

Mid-frequency case: $$Z_T = MR_L/L, \quad \text{when } (\omega^2 LC = 1)$$

Low frequency case: $$Z_T = \frac{\omega M}{\left[(\omega L/R_L)^2 + 1\right]^{1/2}}$$

where

Z_T is the transfer impedance;

M is the mutual inductance between primary and secondary windings ;

L is the inductance of secondary winding;

R_L is the load impedance of secondary (usually 50 Ω) ;

C is the distributed capacitance of secondary;

ω is the angular frequency in radian/second.

The following conclusions result from these equations:

1) The maximum transfer impedance at mid-frequency, for a constant load impedance, is directly proportional to the ratio of mutual inductance to secondary inductance (R_L being constant).

2) The high-frequency half-power point occurs when the reactance of the secondary distributed capacitance is equal to the load resistance.

J.3 Deleterious effects of current probe measurements

The current probe is essentially a toroidal transformer and therefore reflects the secondary impedance into the primary. For an 8-turn secondary winding and a 50 Ω load, typically the insertion impedance is approximately 1 Ω. As long as the combination of source and load impedances of the circuit to be measured is greater than 1 Ω the application of the current probe will not greatly alter the primary current flow. However, if the sum of the circuit source and load impedances is less than the insertion impedance, the application of the current probe may alter the primary current considerably.

* MIT Staff: *Magnetic Circuits and Transformers*, John Wiley & Sons, Inc., New York, N.Y., 1947

One intended current probe application is the measurement of disturbance current on primary power lines which may carry up to 300 A of d.c. or 100 A of a.c. The current probe may also be used in the vicinity of devices which generate strong external magnetic fields. The current probe transfer impedance shall not be altered by these power currents or flux densities. Therefore, the magnetic circuit shall be designed so that it will not saturate. Since the a.c. power currents may be in the frequency range of 20 Hz to 15 kHz, the current probe output at these power frequencies may damage the input circuit of the associated receiver. A possible solution is the insertion of power-frequency rejection filters between the current probe and the receiver. Figure 31 shows a high-pass filter with 9 kHz cut-off frequency.

J.4 Typical frequency response characteristics of current probes

Figure 32 shows the typical frequency response characteristics of current probes, with flat passbands of: a) 100 kHz to 100 MHz; b) 30 MHz to 300 MHz; and c) 200 MHz to 1 000 MHz.

J.5 A shielding structure for use with current probes

A current probe with the addition of a conductive (e.g., copper, brass, etc.) shielding structure may be used to measure either asymmetric (common mode) or symmetric (differential mode) disturbance current. The method is usable from 100 kHz to 20 MHz. The essential feature of this method is a modified RF current probe combined with a high-pass filter. The purpose of the high-pass filter is to enhance the rejection of the power frequency current in the output of the current probe. The test arrangement is described in part 2 of CISPR 16.

J.5.1 *Theoretical model*

The set-up for current measurement using the artificial mains network is shown in figure 33a. The components of the disturbance currents are:

- I_1 current in the live mains conductor
- I_2 current in the neutral mains conductor
- I_C asymmetric current
- I_D symmetric current

NOTE - The phase angle between I_1 and I_2 is assumed zero. This is the case for leads of less than 1 m and frequencies below 30 MHz.

It can be seen from figures 33a) and 33b) that the currents have the following relations:

$$I_1 = I_C + I_D$$

$$I_2 = I_C - I_D$$

$$2\,I_C = I_1 + I_2$$

$$I_D = I_1 - I_2$$

Thus a current probe clamped around the conductors so that I_1 and I_2 would add gives an output due solely to the asymmetrical current; whereas, subtraction of the currents would yield an output related only to the symmetrical current. A 6 dB correction of the measured value only for the asymmetrical current is required due to the factor of 2 in the equation for the asymmetrical current (see figure 33b).

J.5.2 *Construction of the shielding structure*

The additional shield required is shown in figure 34. The dimensions shown are for a current probe with a centre core of 51 mm diameter. For other sizes of current probes the dimensions are scaled accordingly.

This structure serves to position the unshielded conductors in the current probe and to provide additional shielding from any external linkage when the output is grounded at one end. Insulated (0,75 mm^2), stranded wire is passed through the hole and fitted at each end with terminals to accept the shielded leads from the mains network and to the equipment under test. The diameter of the center of the shield is the built-up with insulating tape so that the wires are firmly held in the slots and so that this portion of the assembly fits snugly in the current probe when it is closed.

The shield is positioned in the current probe such that the plane of the leads is perpendicular to the plane of the gaps in the core halves of the probe. It is important to ensure that the shielding structure as shown in figure 34 is insulated from the current probe housing so that the gap in the housing is not shorted.

J.5.3 *High-pass filter*

A high-pass filter, if needed, is inserted between the output of the current probe and the measuring receiver. This filter may be part of the measuring receiver. (See figures 31 and 33b).

J.6 Calibration of current probes

Calibration of current probes may be done by a jig which is made of two halves of a coaxial adapter. When assembled with the current probe in place, it forms a coaxial line the outer conductor of which encloses the current probe and the inner conductor passes through the probe aperture (see figure 38).

The equivalent calibration circuit is shown in figure 35. When the coaxial line is well matched the current I_P through the inner conductor may be calculated from a measurement of the voltage V_1 on the line. The body, if metal, or shield of the probe should be taken into account in the design of the jig to achieve a good coaxial line. If the voltage output of the current probe is V_2 the transfer admittance may be calculated using the following formula:

$$k = V_1 - V_2 - 34$$

where

k is the transfer admittance in dB(S);

V_1 is the RF voltage on the coaxial line in dB(μV);

V_2 is the RF output voltage of the probe in dB(μV);

the factor 34 is related to the 50 Ω load impedance.

The transfer admittance k is used to calculate the value of the measured current I_p by the formula:

$$I_P = V_2 + k$$

where

I_p is in dB(μA), and

V_2 is in dB(μV)

k is in dB(s)

Figure 36 shows a typical calibration result, figure 37 shows the return loss and figure 38 shows picture of the coaxial adapter jig.

Annex K
(informative)

Construction of the absorbing clamp
(clause 13)

Examples of absorbing clamp construction.

Figures 38 and 39 show two examples of the absorbing clamp. The three main parts of the absorbing clamp described in 13.2 are the current transformer C, the power absorber and impedance stabilizer D, and the absorbing sleeve E. D consists of a number of ferrite rings and E consists of ferrite rings or tubes. The core of the transformer C has two or three rings of the type used in D. The secondary winding of the current transformer consists of a turn of a miniature coaxial cable encircling the rings and connected as shown. The cable is passed through the sleeve E to a coaxial terminal on the clamp. C and D are mounted close together and aligned on the same axis to permit movement along the lead B under measurement. Sleeve E is usually mounted alongside absorber D for practical reasons. Both D and E serve to attenuate asymmetric currents on the leads through them.

The example in figure 39 shows some features of improvements to the absorbing clamp performance. A metal cylinder (1) is mounted inside the core of the transformer C to act as a capacitive shield. This cylinder is split into two halves. A insulating tube (2) is used to centralize the lead within the transformer. This tube extends from the input end of the transformer to the first ring of the absorber D, and is for use during clamp calibration and for small diameter leads.

Annex L
(informative)

Construction details for open area test sites in the frequency range of 30 MHz to 1 000 MHz
(clause 16)

L.1 General

Subclauses 16.0 through 16.5 contain major construction considerations for open area test sites. Additional details that are helpful in assuring a well constructed site and all weather enclosure are described in this annex. A positive way to assure the suitability of these practices is to perform NSA measurements as described in 16.6.

L.2 Ground plane construction

L.2.1 *Material*

Metal is the recommended ground plane material for field strength test sites. However, for practical reasons, metallic ground planes cannot be specified for measurement of all equipment. Some examples of metallic ground planes include solid metal sheets, metal foil, perforated metal, expanded metal, wire cloth, wire screen and metal grating. The ground plane should have no voids or gaps with linear dimensions that are an appreciable fraction of a wavelength at the highest measurement frequency. The recommended maximum opening size for screen, perforated metal, grating or expanded metal type ground planes is 1/10 of a wavelength at the highest frequency of measurement (about 3 cm at 1 000 MHz). Material comprised of individual sheets, rolls, or pieces should be soldered or welded at the seams preferably continuously but in no case with gaps longer than 1/10 wavelength. Thick dielectric coatings, such as sand, asphalt, or wood on top of metal ground planes may result in unacceptable site attenuation characteristics.

L.2.2 *Roughness*

The Rayleigh roughness criterion provides a useful estimate of maximum allowable r.m.s. ground plane roughness (see figure 43). For most practical test sites, especially for 3 m separation applications, up to 4,5 cm of roughness is insignificant for measurement purposes. Even more roughness is allowed for 10 m and 30 m sites. The site validation procedure in 16.6 shall be performed to determine whether the roughness is acceptable.

L.3 Services to EUT

Electrical service or mains wiring to the EUT should be run under the ground plane to the maximum extent possible and preferably at right angles to the measurement axis. All wires, cables, and plumbing to the turntable or mounting of the EUT should also be run under the ground plane. When underground routing is not possible, service to the EUT should be placed on top of, but flush with, and bonded to the ground plane.

L.4 Weather protection enclosure construction

L.4.1 *Materials and fasteners*

Up to 1 000 MHz, thin sections of fibreglass and most other plastics, specially treated woods, and fabric material will not cause appreciable attenuation of EUT emissions. Moisture absorption in some materials (e.g., wood and nylon), however, can cause transmission losses which are particularly critical if EUT emissions are measured through such material. Care should be taken to ensure that air-deposited conductive particles and standing water and ice do not build up on the structure or within the material forming the structure. Inspections should be made periodically for foreign objects which might lodge on the structure causing measurement errors.

Use of metal above the ground plane should be kept to a minimum. Use of plastic or fabric fasteners is highly recommended. Any anchors, pilings, or similar foundations should be far enough removed from the test area so as not to affect the measurement.

L.4.2 *Internal arrangements*

All structural members should be non-reflective. Any blowers or ducts for heating, cooling or air support should be outside the test area or outside the structure, unless they are made of non-conductive material or run below a metallic ground plane or well below a non-metallic ground plane. Temperature and humidity control may be required for the operation of the equipment. Any insulation or windows should be free of metal backing or framing. Any safety rails or stairs should also be non-conductive if located above the ground plane.

L.4.3 *Size*

The size of a weather protection enclosure will depend upon the size of the EUT and whether or not the entire antenna range is to be enclosed or only the area over the EUT, the area over the measuring set, or the area enclosing the receive antenna positioner and the highest extent of the receiving antenna when making vertical polarization measurements.

L.4.4 *Uniformity with time and weather*

It is recommended that periodic normalized site attenuation measurements be made in order to detect anomalies caused by degradation of the all-weather protection due to weather conditions (e.g. moisture absorption) or contamination of enclosure materials. This measurement also checks the calibration of RF cabling and test instrumentation. A six-month interval is generally adequate unless physical signs indicate material degradation sooner, i.e. material changes colour due to air-borne contaminants.

L.5 Turntable

A turntable is recommended for convenience in measuring electromagnetic emissions from all sides of the EUT. For testing a floor-standing EUT, the turntable should be metal-covered, flush with the ground plane and conductively connected to it. A non-metallic turntable above the ground plane surface or combination of metallic turntable and non-metallic table sitting on top of the turntable may be used for testing a table-top EUT. A slightly raised, non-metallic turntable may also be acceptable for testing floor-standing EUT.

L.6 Receiving antenna mast installation

The receiving antenna should be mounted on a non-conducting support which will allow the antenna to be raised between 1 m and 4 m for measurement distances of 10 m and less, and between 1 m and 4 meters, or between 2 m and 6 m for distances greater than 10 m. The cable shall be connected to the antenna balun such that for horizontally polarized antennas the cable is orthogonal to the axis of the antenna elements at all antenna heights in order to maintain balance with respect to ground. The cabling from the receiving antenna balun should drop vertically to the ground plane approximately 1 m or more to the rear of the receiving antenna. From that point it should be kept on or under the ground plane in a manner so as not to disturb the measurement. The cable between the antenna and disturbance analyzer should be as short as practical to ensure acceptable received signal levels at 1 000 MHz.

For vertically polarized dipole-type antennas, the cabling to the measuring receiver should be maintained horizontal, i.e., parallel to the ground plane, for a distance of approximately 1 m or more to the rear of the receiving antenna (away from the EUT) before dropping to the ground plane. An antenna boom approximately 1 m in length will suffice. The remaining cable routing to the analyzer is the same as for the horizontally-polarized case.

For both cases, the antenna factor calibration should not be affected by the presence of the antenna positioners and disposition of the coaxial cabling attached to the antenna.

Annex M
(informative)

Basis for 4 dB site acceptability criterion
(clause 16)

M.1 General

This annex shows the basis for the acceptability criterion of ±4 dB for the normalized site attenuation measurements required in 16.6.

M.2 Error analysis

The error analysis in table M applies to the normalized site attenuation measurement methods given in 16.6. The total estimated errors are the basis for the ±4 dB site acceptability criterion consisting of approximately 3 dB measurement uncertainty and an additional allowable 1 dB for site imperfections.

The error budget in table M does not include uncertainties in the amplitude stability of the signal generator, tracking generator, or any amplifiers that may be used, nor does it include the potential errors in measurement technique. The output level of most signal and tracking generators will drift with time and temperature, and the gain of many amplifiers will drift as temperature changes. It is imperative that these sources of error be held to an insignificant amount or corrected in making the measurements, otherwise the site may fail to meet the acceptability criterion due to instrumentation problems alone.

Table M – Error budget

Error item	Measurement method	
	Discrete method dB	Sweep frequency method dB
Antenna factor (Tx)*	±1	±1
Antenna factor (Rx)*	±1	±1
Voltmeter	0	±1,6**
Attenuator	±1	0
Site imperfections	±1	±1
Totals	±4	±4,6

* At frequencies above 800 MHz, AF errors may approach ±1,5 dB

** From the operating instructions.

From the operating instructions for some automatic spectrum analyzers, for example, if everything is done to remove or compensate every potential error as much as possible the remaining amplitude errors are:

1) ±0,2 dB calibrator uncertainty,
2) ±1,0 dB frequency response flatness,
3) ±1,0 dB input attenuator switching,
4) ±0,4 dB RF and IF gain uncertainty.

This gives a total potential error of ±2,6 dB. This does not include ±0,05 dB/K temperature drift. In practice, when performing substitution type measurements the errors associated with the frequency response flatness and input attenuator switching are usually 1 dB less, so that the total error band for the spectrum analyzer as a two-terminal voltmeter is ±1,6 dB or less, which is used in table M.

Many attenuators have far poorer absolute accuracy, but some are better. The total error budget could thus be increased or decreased in the discrete measurements. If an external attenuator is used with the automatic spectrum analyzer in the swept frequency measurements this error budget is also increased.

These error budgets do not contain errors from time and temperature induced drifts of the gains, output levels, or amplitude responses of the test equipment. Such errors may exist and steps shall be taken to avoid them by making the measurements as rapidly as possible.

In practice, the errors accounted for above seldom are all in the same direction. Meeting the ±4 dB criterion for a well constructed and located site may actually allow more than ±1 dB site anomaly variation from ideal.

Annex N
(informative)

Construction of the coupling units for current injection for the frequency range 0,15 MHz to 30 MHz
(clause 18)

N.1 Coupling unit type A for coaxial antenna input

The circuit diagram and construction are similar to the type A unit shown in figure 44, except that the inductance value is 280 µH.

Construction of the 280 µH inductor:

Core: two ferrite rings, material 4C6 or equivalent, placed together, dimensions 36 mm outer diameter, 23 mm inner diameter, 30 mm thick.

Winding: 28 turns of a fully screened miniature coaxial cable, e.g. UT-34, wire diameter 0,9 mm, with an outer insulation plastic tubing of 1,5 mm outer diameter.

N.2 Coupling unit type M, for mains leads

The circuit diagram and construction are similar to the type M unit shown in figure 45, except that the two inductors are 560 µH each, and C_1 = 0,1 µF and C_2 = 0,47 µF.

Construction of the 560 µH inductor:

Core: two ferrite rings, material 4C6 or equivalent, placed together, dimensions 36 mm outer diameter, 23 mm inner diameter, 30 mm thick.

Winding: 40 turns of insulated copper wire, 1,5 mm outer diameter.

N.3 Coupling unit type L, for loudspeaker leads

The circuit diagram and construction are similar to the type L unit shown in figure 46 with two separate inductors of 560 µH each and C_1 = 47 nF and C_2 = 0,22 µF.

Construction of each 560 µH choke:

Core: one ferrite ring, material 4C6 or equivalent, dimensions 36 mm outer diameter, 23 mm inner diameter, 15 mm thick.

Winding: 56 turns of varnish insulated copper wires, 0,4 mm diameter.

NOTE - Characteristics of magnetic ferrite type 4C6:

Relative initial permeability	μ_i	= 120
Loss factor	$tg\delta/\mu_i$	< 40 at 2 MHz, < 100 at 10 MHz
Resistivity	ρ	= 10 kΩm

N.4 Coupling unit type Sw, for audio-frequency signals

The circuit diagram and construction are similar to the type Sw unit shown in figure 47, except with the 280 µH inductor described in N.1. The screened cable may be an audio-frequency type, and its diameter shall be not larger than 2,1 mm.

NOTE - The type A coupling unit described in N.1 may be used for this purpose, if the two stereo signal cables of the equipment under test are connected together.

N.5 Coupling unit type Sw, for audio, video, and control signals

The circuit diagram and construction are similar to the type Sw unit shown in figure 48, except with two 560 µH inductors constructed as described in N.2. The cable with three conductors shall have an outer diameter not larger than 1,5 mm. This may be achieved using two micro-coaxial cables type UT-20 (0,6 mm diameter) and a varnish insulated copper wire of 0,3 mm diameter.

Annex P
(informative)

Principle of operation and examples of coupling units for conducted current immunity measurements
(clause 18)

P.1 Principle of operation

The principle of operation is illustrated in figure 49. The inductance L presents a high impedance to the injected disturbance current. The filter L/C_2 isolates the test apparatus (wanted signal generator or auxiliary equipment); C_1 and C_2 may be replaced by a short circuit if the a.c/d.c. conditions permit. The disturbance signal delivered from a generator with 50 Ω internal resistance is injected via a 100 Ω resistor R_1 and a blocking capacitor C_1 (if required) on to the leads or on to the shield of a coaxial cable.

P.2 Types of unit and their construction

The following types of coupling units are used:

Type A: The RF coaxial units are to be used for coaxial leads carrying wanted signals in the RF frequency range. The construction details are shown in figure 44. The 100 Ω resistor (to make up the 150 Ω source impedance from a 50 Ω interference signal source) is bonded to the shield of the coaxial output connector in the unit.

Type M: These are for use with mains leads. The construction details are shown in figure 45. The injection of the disturbance current is done asymmetrically on both wires through an equivalent resistance of 100 Ω. This unit is like an artificial mains delta network and presents, as seen from the equipment under test terminals, a symmetrical and asymmetrical equivalent resistive impedance of 150 Ω.

Type L: These are for use with loudspeaker leads. The construction details are shown in figure 46. The impedance of the disturbance source is arranged as for Type M units.

Type Sr and Sw: These are designed for use with audio, video and other auxiliary leads. They are multi-pin units which have to be adapted to a variety of pin numbers and connector configurations, as follows:

Type Sw: These units provide a through path for audio, video, control or other signals, in which case filtering is required to ensure that the disturbance signal is directed towards the equipment under test. The construction details shown in figure 47, indicate the simple filtering provided for audio signals with a screened pair wound on a toroid. In the case of multi-lead cables it may be necessary, for construction reasons, to separate the cable leads before winding upon a toroid shown in figure 48. In both cases the disturbance current is injected via a 100 Ω resistor on to the screen and the earth pins of the output connector, the screens of the shielded leads, and through capacitor on to the other (unshielded) leads.

Type Sr: These are designed for the case where there is no requirement to provide a through signal path. All leads of the cable are terminated with a matched load resistance. The construction details are shown in figure 50. The disturbance current is injected via a 100 Ω resistor on to the screen (earthing) and the earth pins of the connector, to which point all the load resistors (R_1 to R_n) are connected also. It should be noted that a coupling unit of the type indicated in figures 47 or 48 terminated with a correct load impedance could be used for this purpose.

If the source impedance of the disturbance generator is not 50 Ω, the value of the series resistor is adjusted accordingly to make up the required 150 Ω impedance.

The RF choke coils shown in figures 44 to 50 have inductance values 30 µH or 2 x 60 µH in parallel and are satisfactory for the frequency range 1,5 MHz to 150 MHz. For the frequency range 0,15 MHz to 30 MHz, the inductance values are 280 µH or 2 x 560 µH in parallel respectively. Annex N describes their construction.

Precautions have to be taken in the layout in order to keep parasitic capacitance to the output terminals of the units as low as possible. It should be noted that the metal cases of the units are to be carefully connected to the ground plane using large section copper braid and unpainted cases.

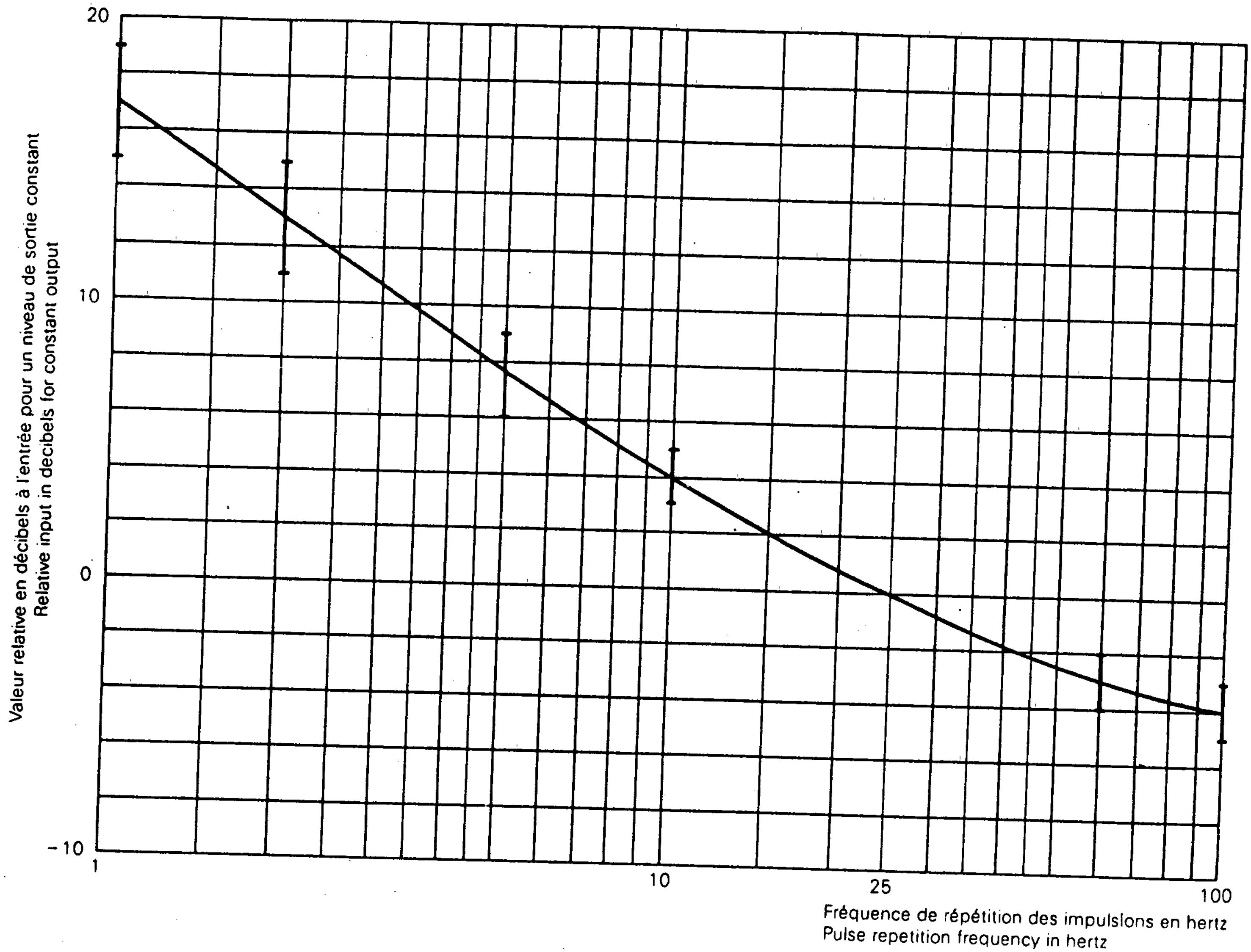


Figure 1a – Pulse response curve (subclause 2.4.2) (Band A)

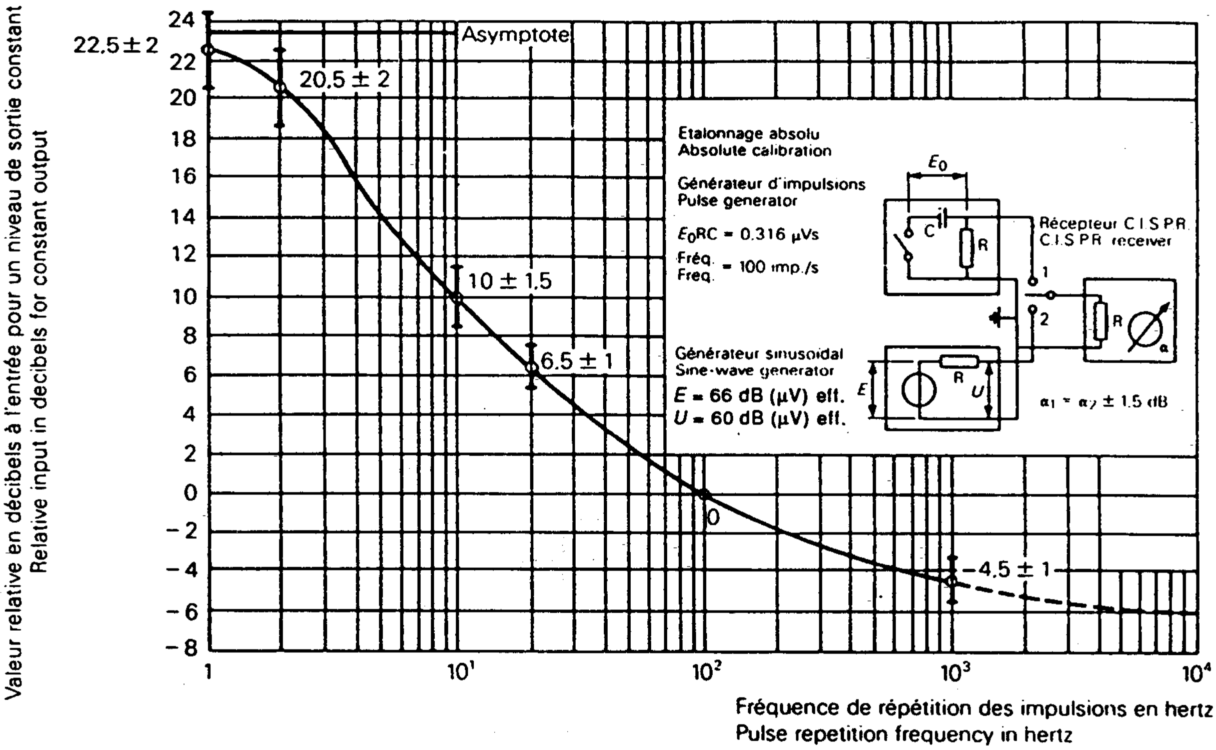


Figure 1b – Pulse response curve (subclause 2.4.2) (Band B)

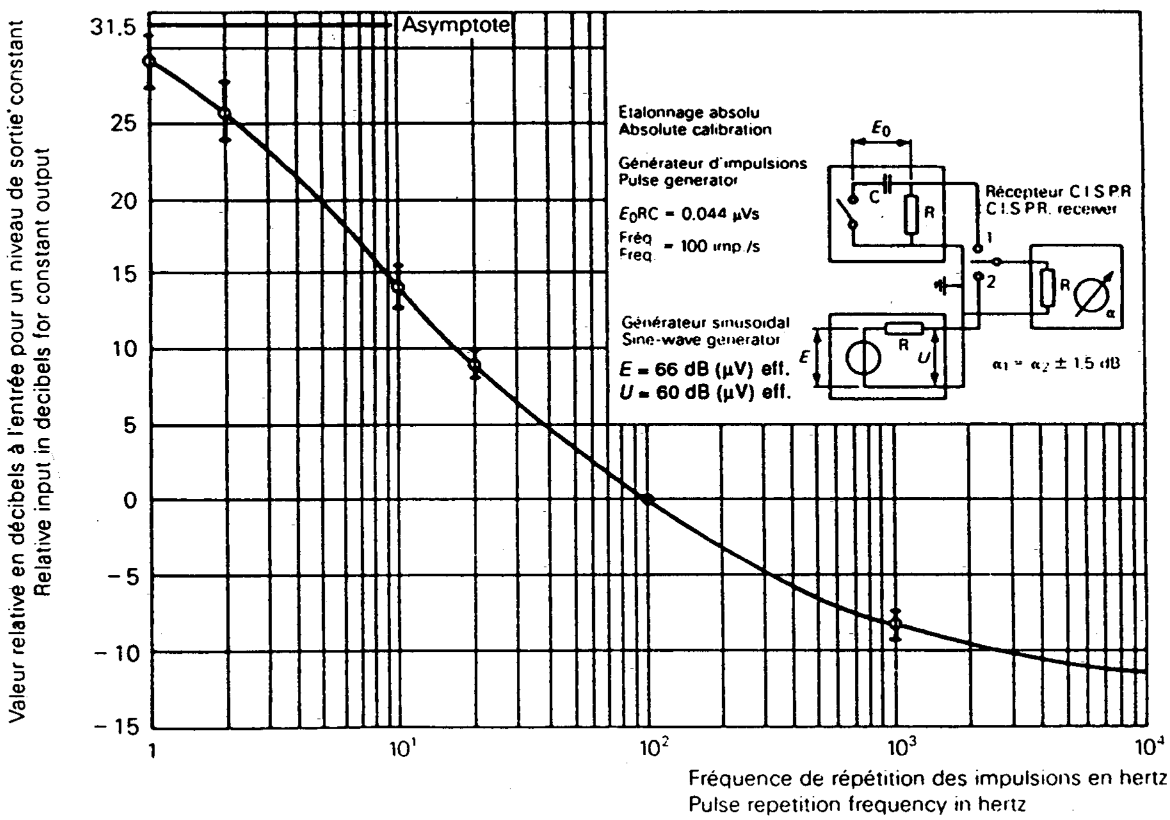


Figure 1c – Pulse response curve (subclause 2.4.2) (Bands C and D)

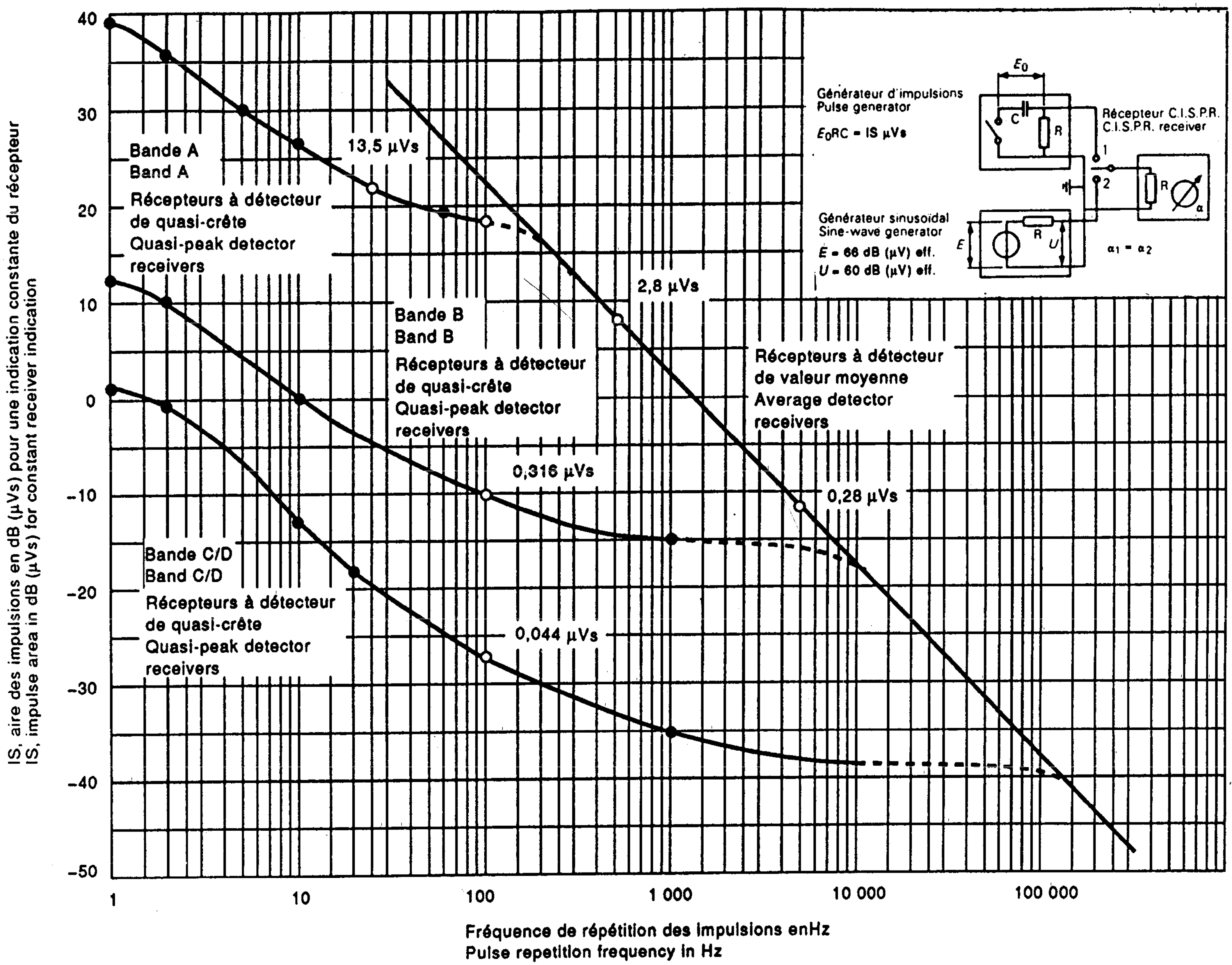


Figure 1d – Theoretical pulse response curves of quasi-peak detector receivers and average detector receivers (subclauses 2.4.2 and 4.4.2)

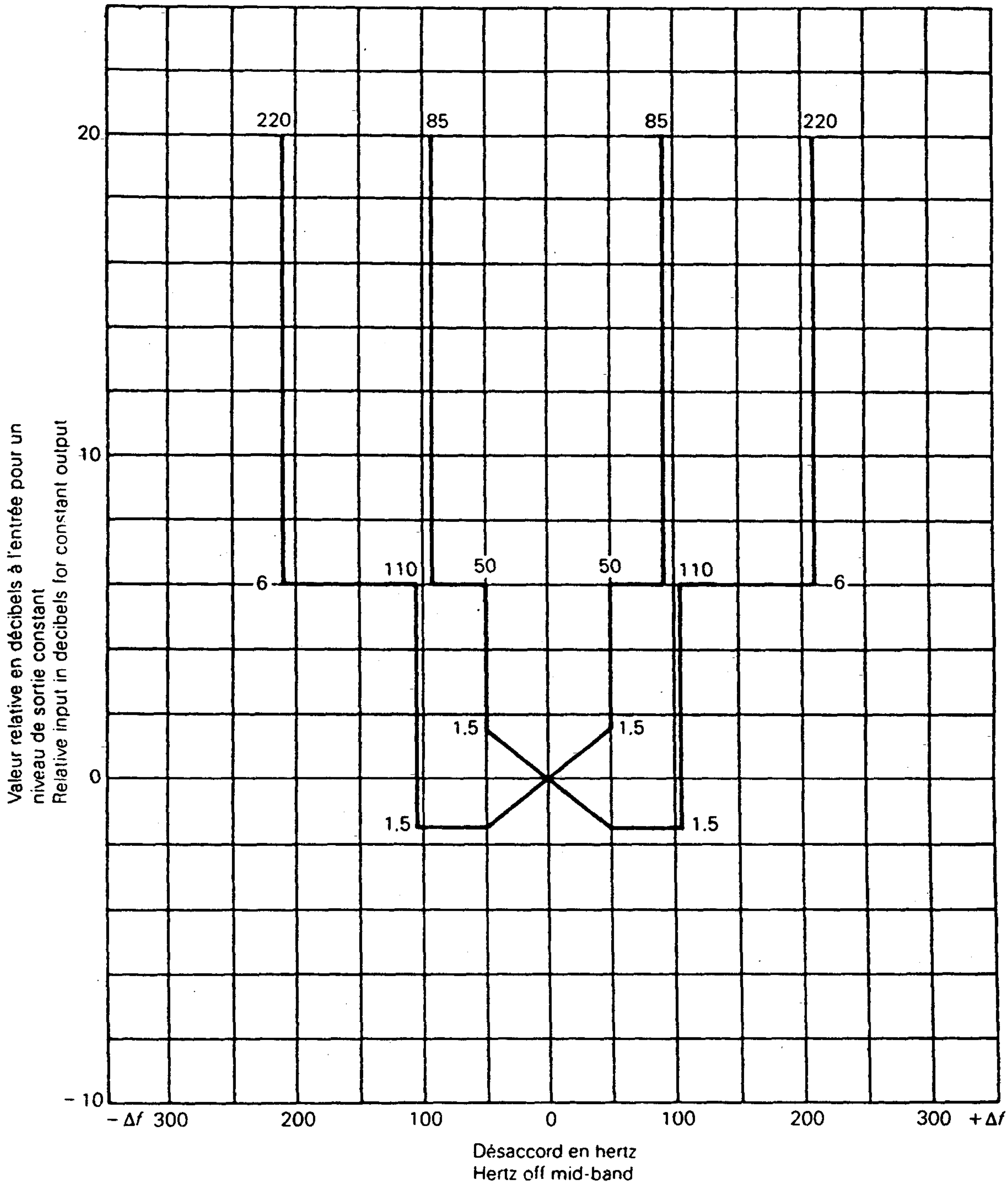


Figure 2a – Limits of overall selectivity – pass-band (subclauses 2.5.1, 3.5, 4.5, 5.5) (Band A)

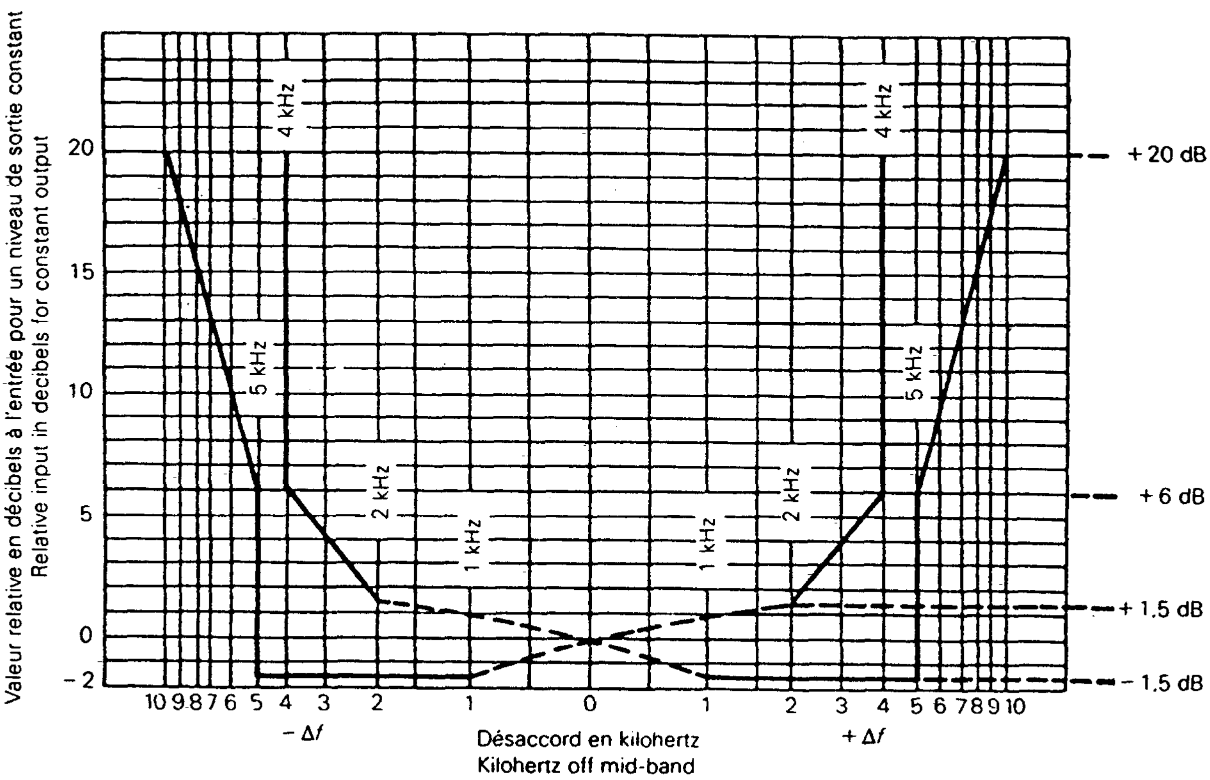


Figure 2b – Limits of overall selectivity – pass-band (subclauses 2.5.1, 3.5, 4.5) (Band B)

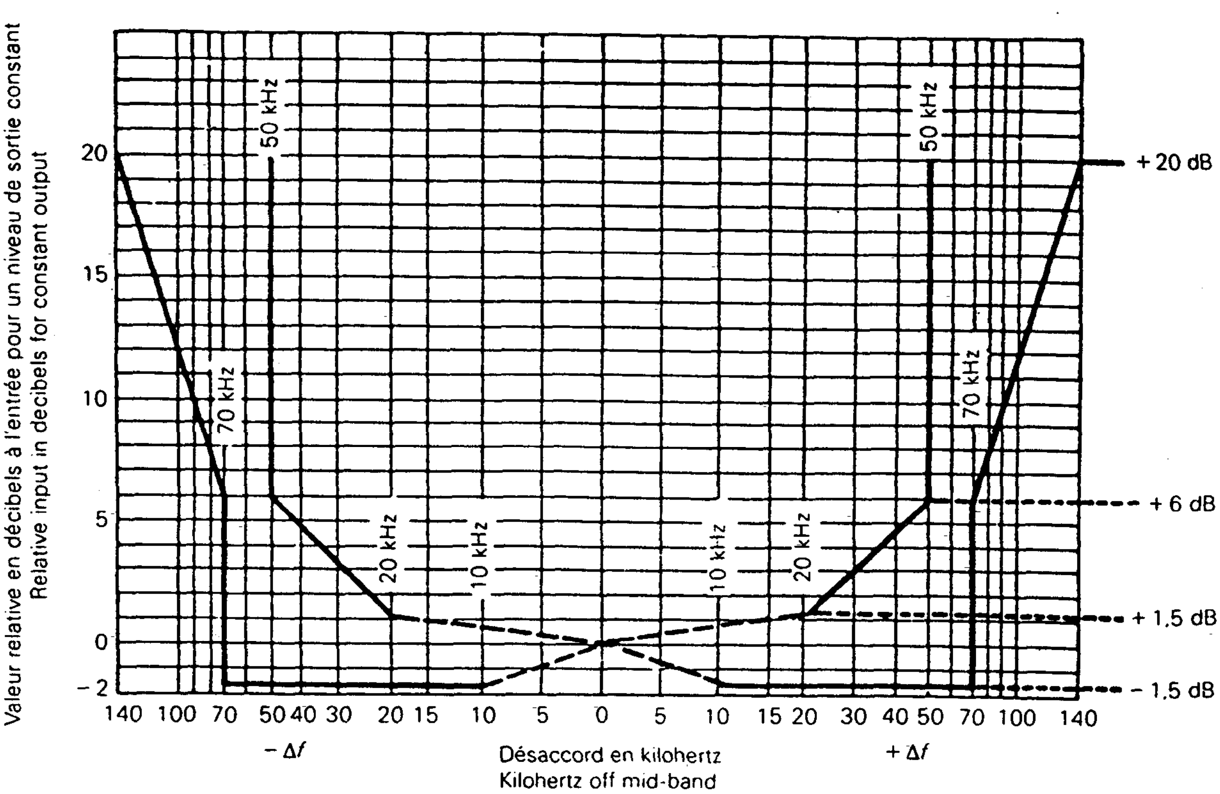
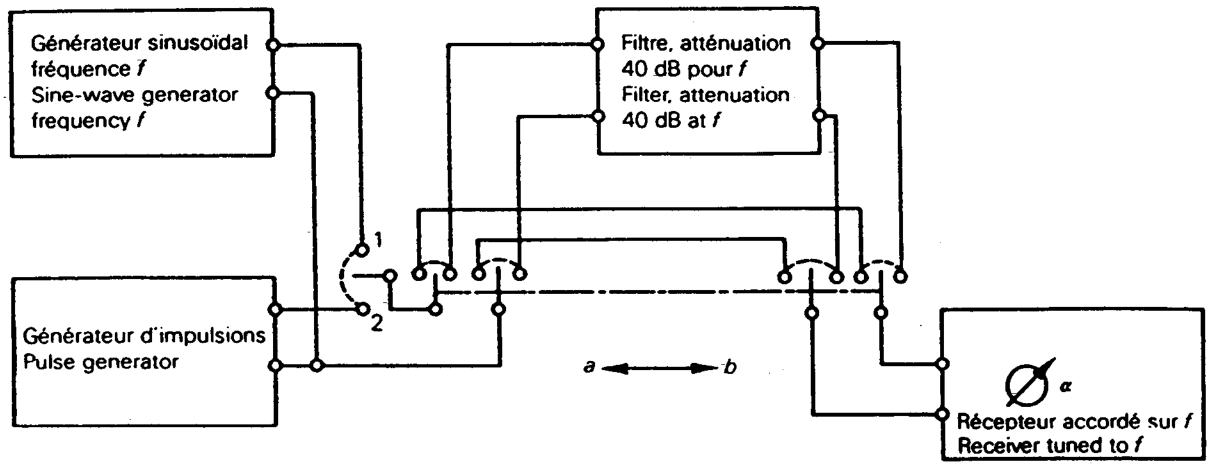


Figure 2c – Limits of overall selectivity – pass-band (subclauses 2.5.1, 3.5, 4.5, 5.5) (Bands C and D)



Responses:

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

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

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

Figure 3 – Arrangement for testing intermodulation effects (subclause 2.6)

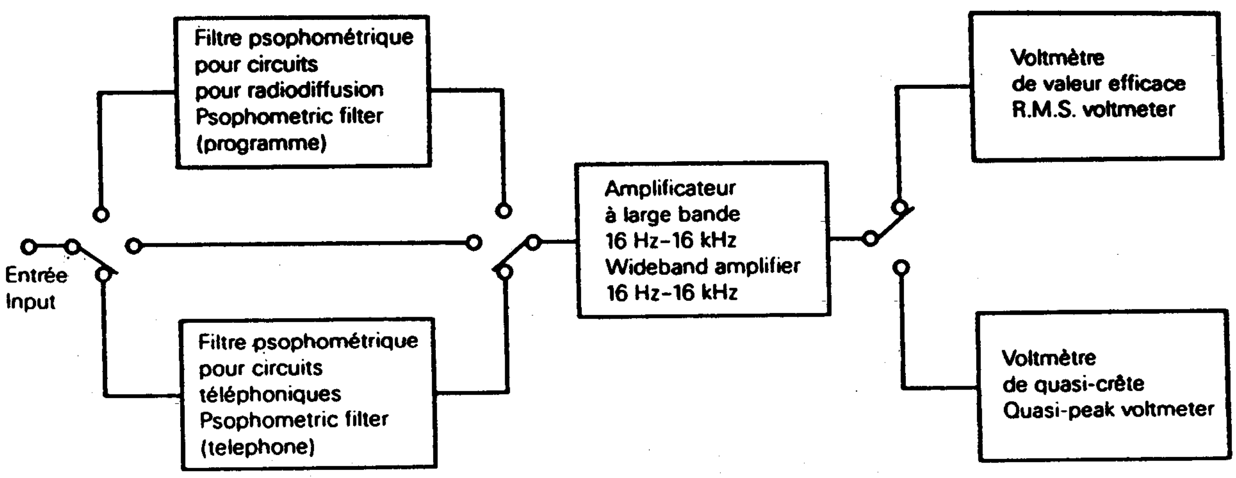


Figure 4 – Block diagram of an audio-frequency interference voltmeter (clause 7)

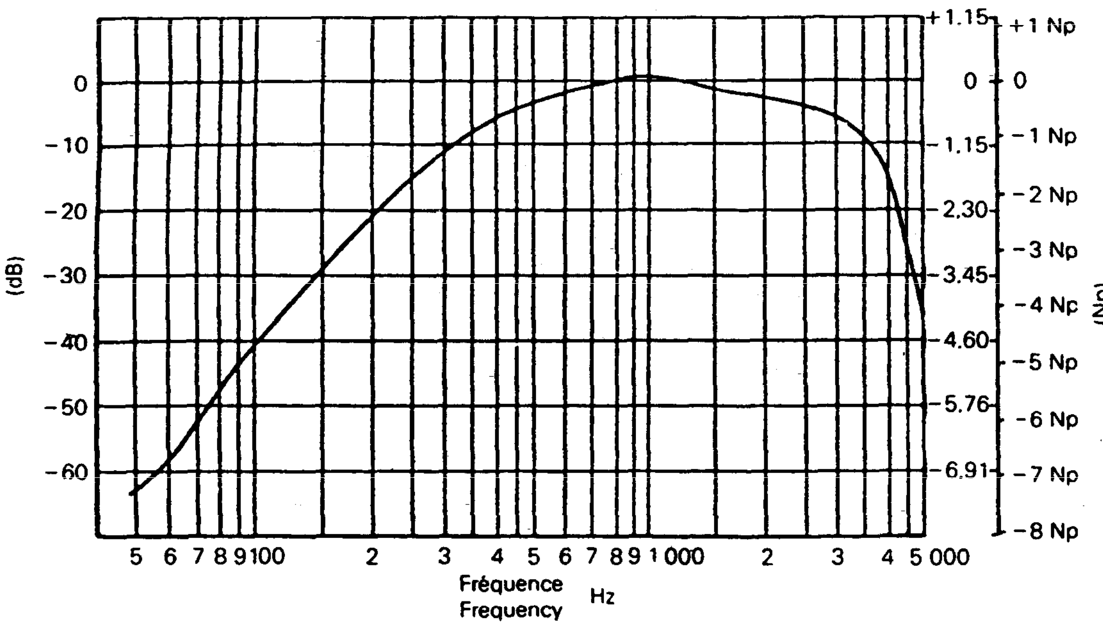


Figure 5 – Characteristic curve of the psophometric filter network used for measurements at the terminals of a commercial trunk telephone circuit (item b) of subclause 7.1.3)

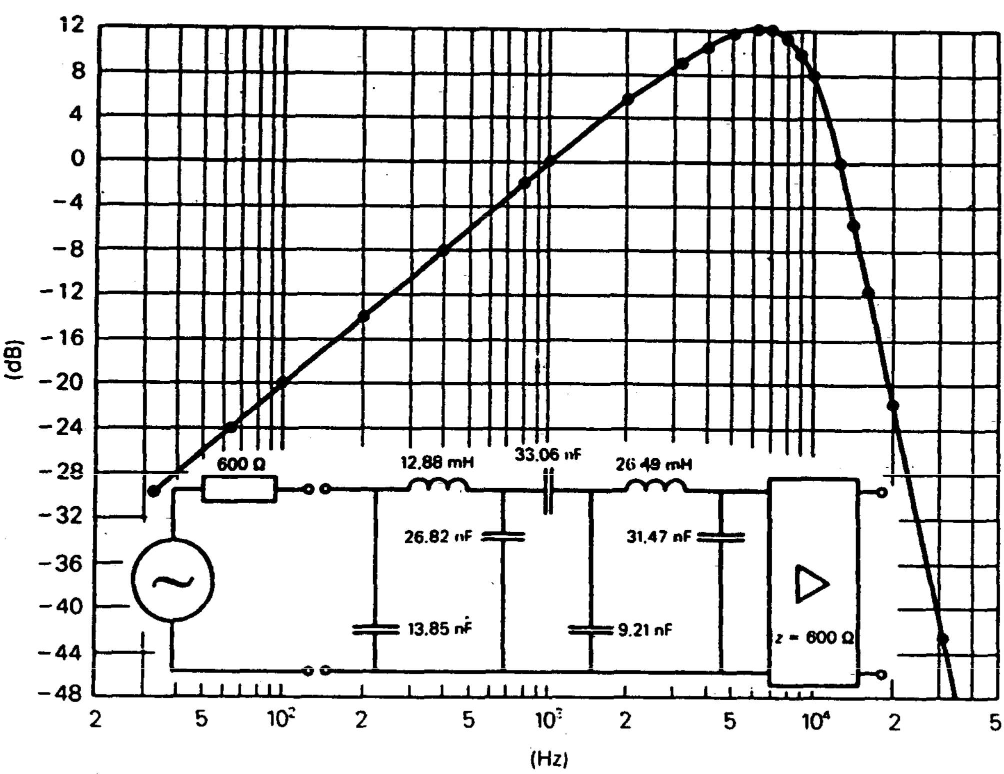
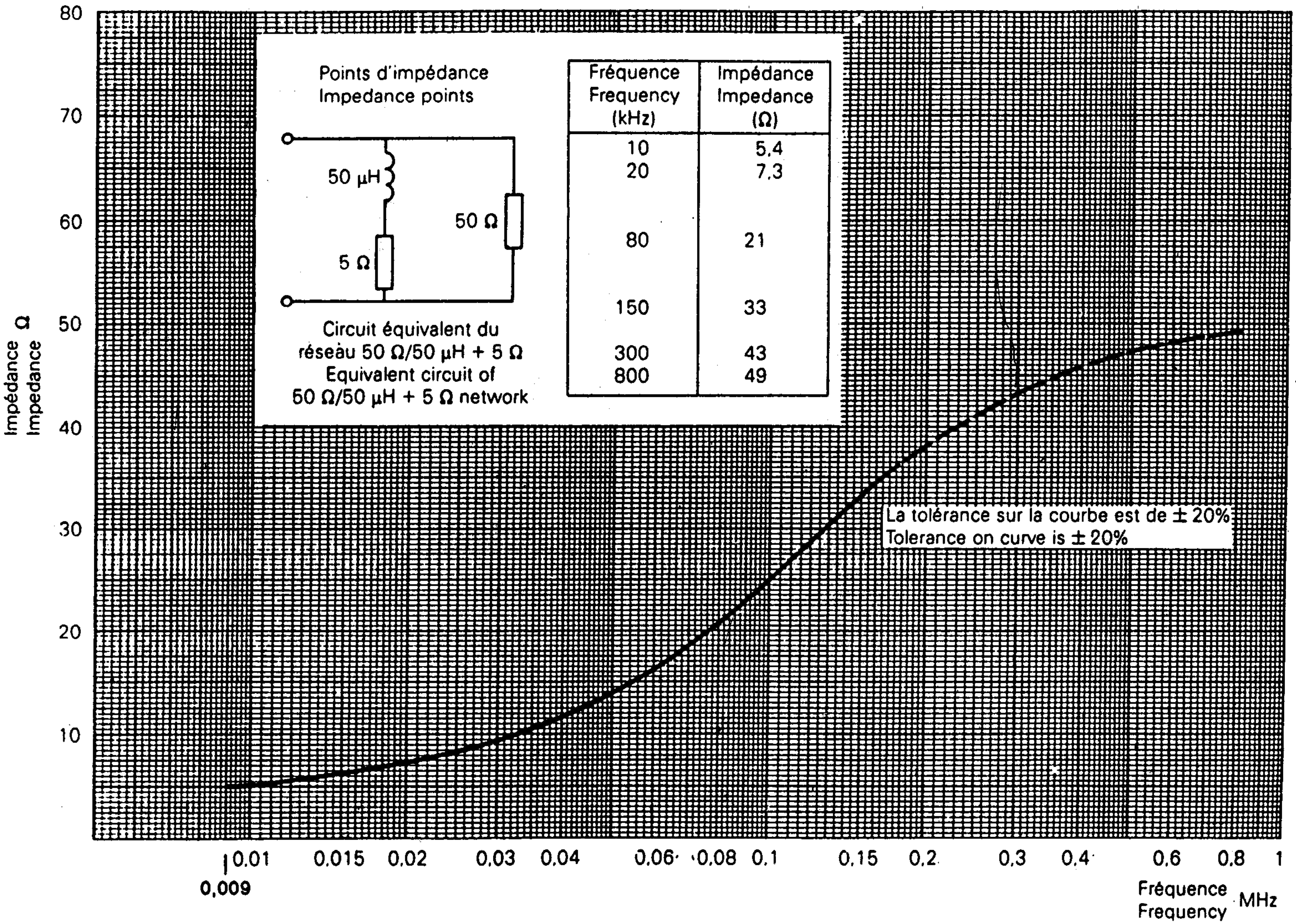
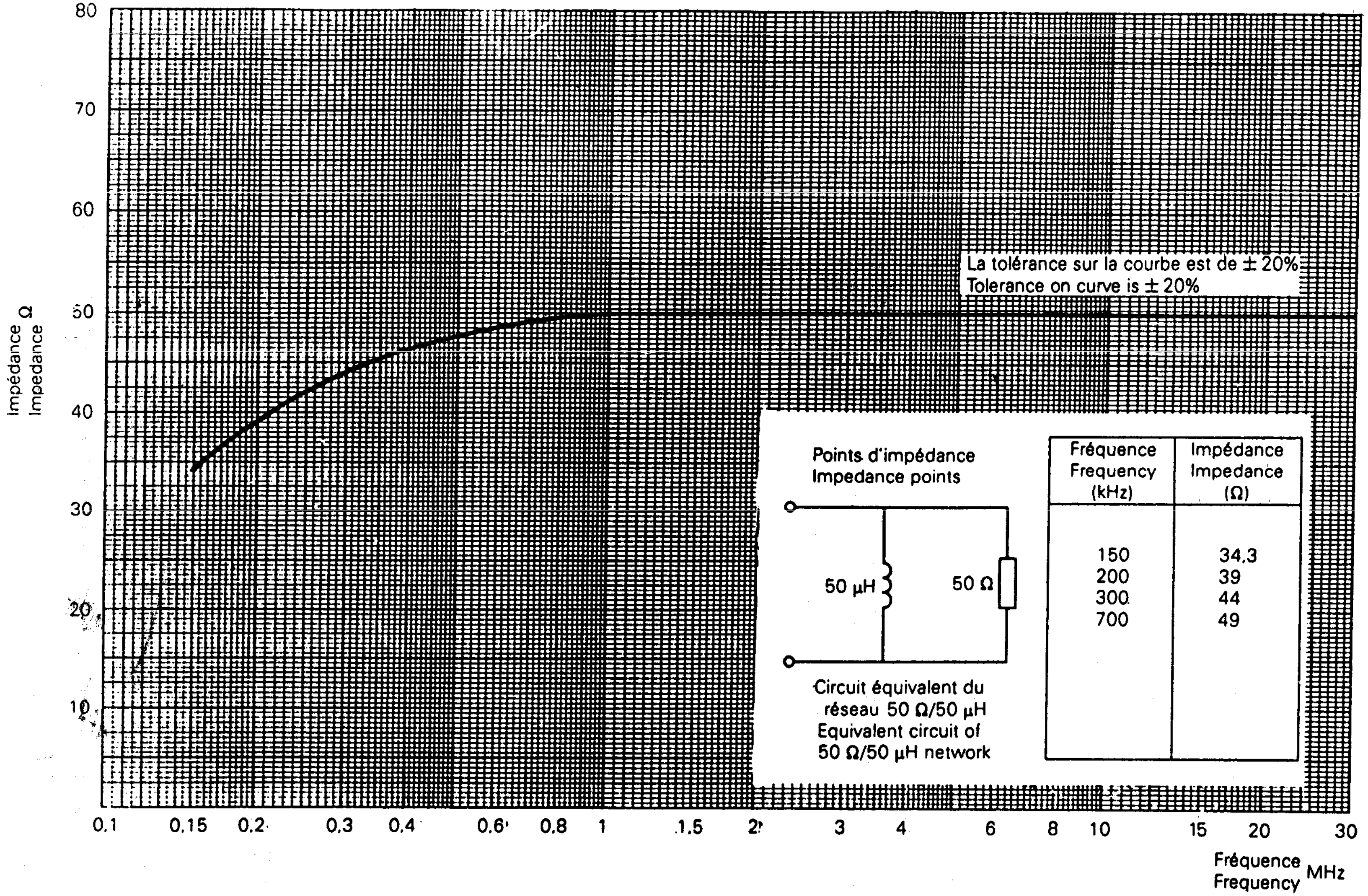


Figure 6 – Weighting network for programme measurements and its response curve (item c) of subclause 7.1.3)



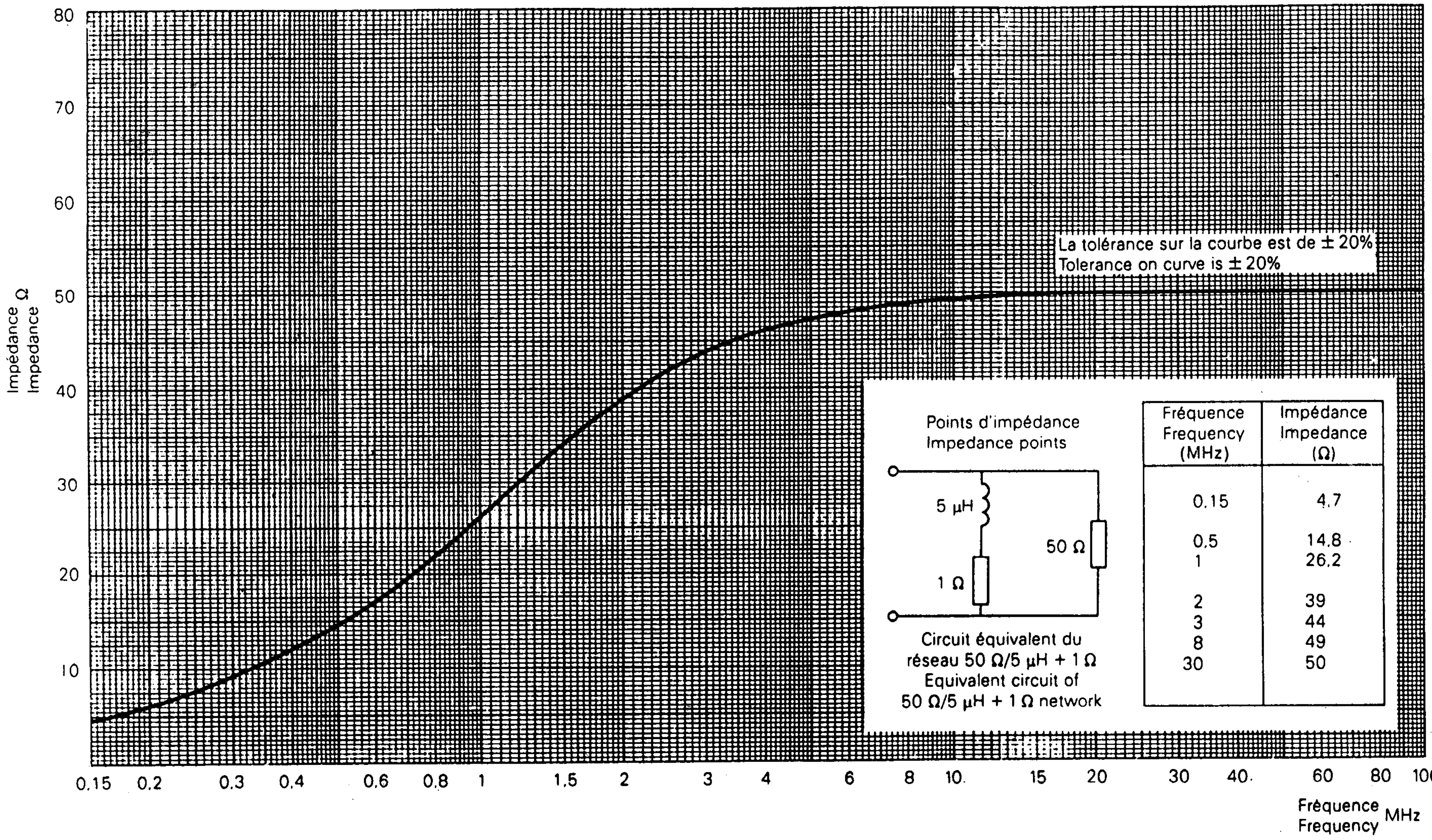
Fréquence Frequency (kHz)	Impédance Impedance (Ω)
10	5,4
20	7,3
80	21
150	33
300	43
800	49

Figure 7a – Impedance of artificial mains network for band A (subclause 11.2)



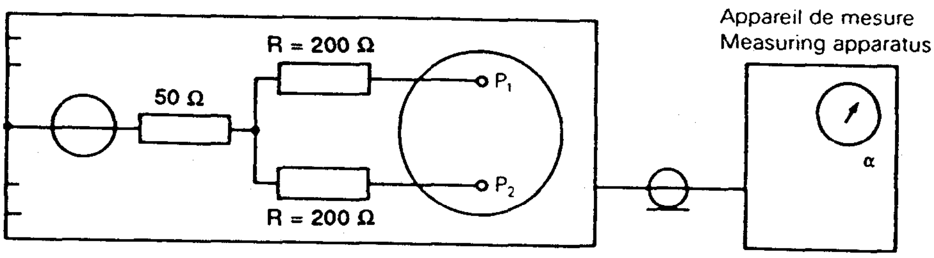
Fréquence Frequency (kHz)	Impédance Impedance (Ω)
150	34,3
200	39
300	44
700	49

Figure 7b – Impedance of artificial mains network for band B (subclause 11.3)



Fréquence Frequency (MHz)	Impédance Impedance (Ω)
0.15	4.7
0.5	14.8
1	26.2
2	39
3	44
8	49
30	50

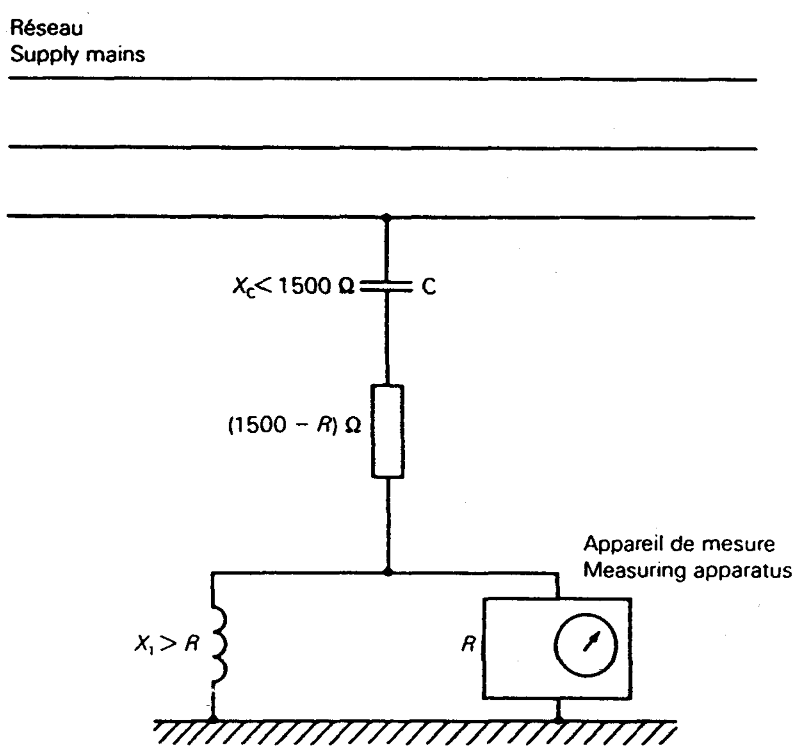
Figure 8 – Impedance of artificial mains network for band B, 0,15 MHz to 30 MHz or band C, 30 MHz to 100 MHz (subclause 11.4)



R are the resistors of 200 Ω equal to each other within 1 %

P_1 P_2 are the terminals of network for connection of device

Figure 9 – Method for checking the balance of the arrangement for the measurement of symmetrical voltages (subclause 11.6.1)



NOTE:

$$V = \frac{1\,500}{R} U$$

where:

V is the disturbing voltage

U is the voltage at the input of the measuring apparatus

Figure 10 – Circuit for RF voltage measurements on supply mains (subclause 12.2)

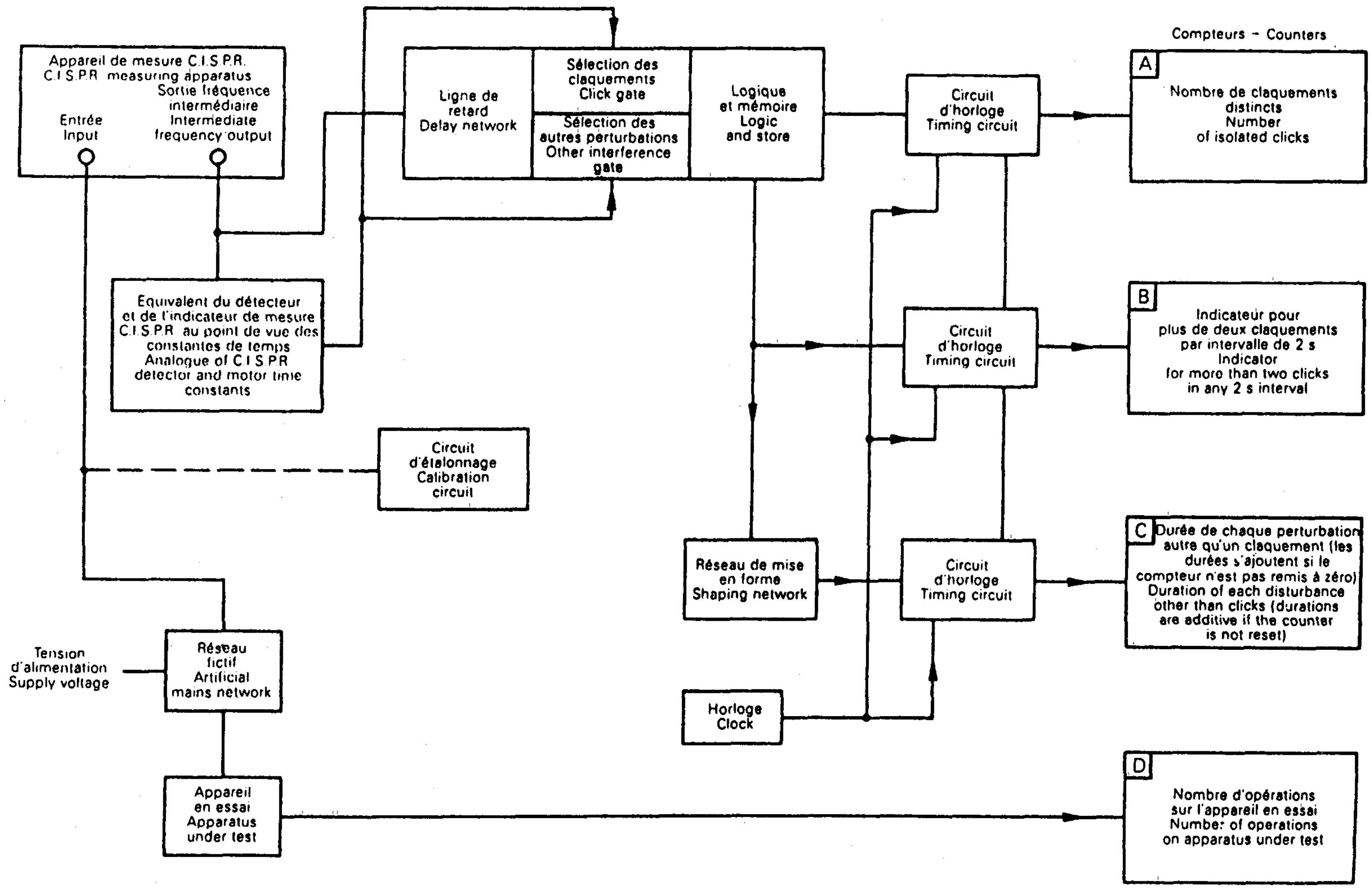


Figure 11 – Example of a disturbance analyzer (subclause 14.1)

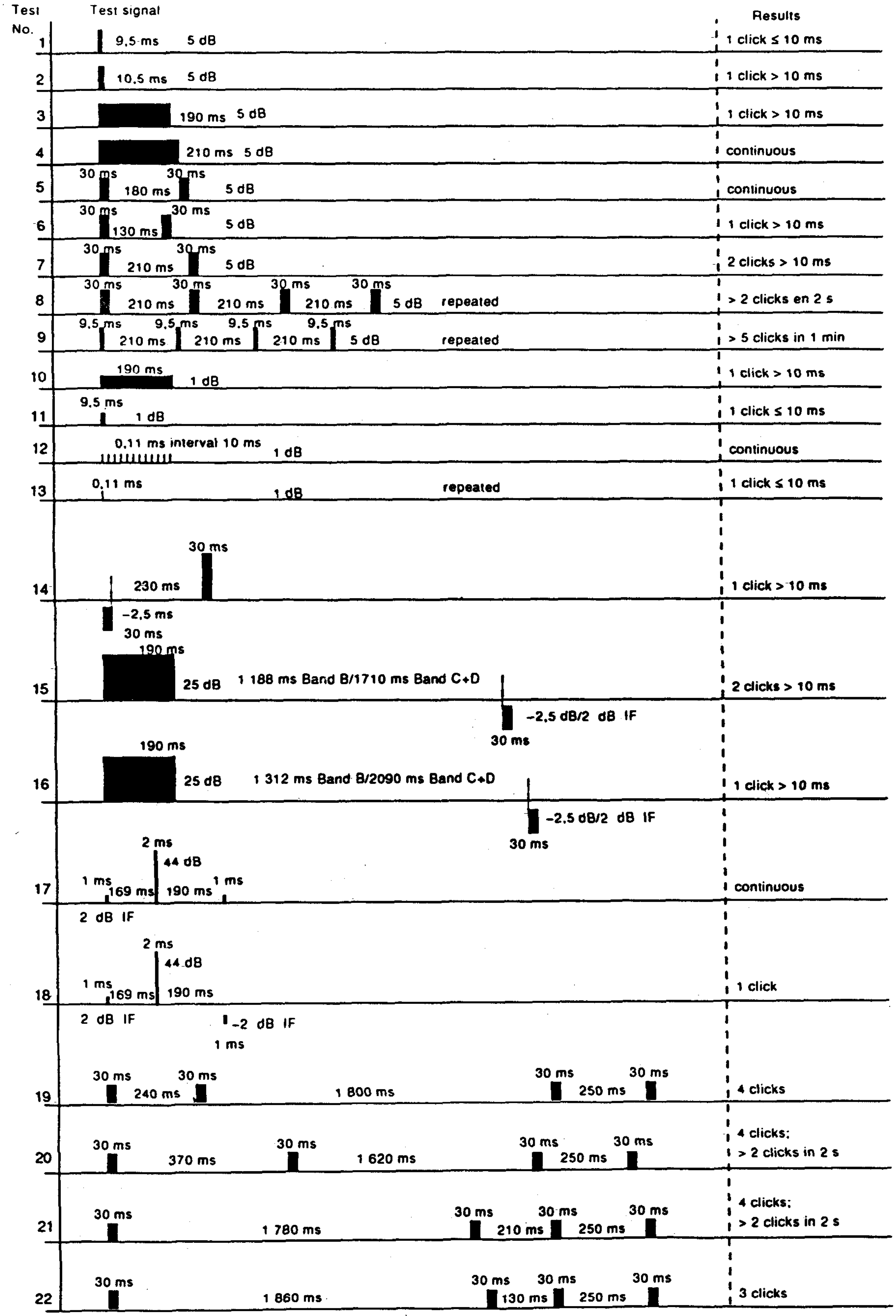


Figure 12 – A graphical presentation of the disturbance analyzer waveforms given in tables 13, 14 and 15 (Subclause 14.1)

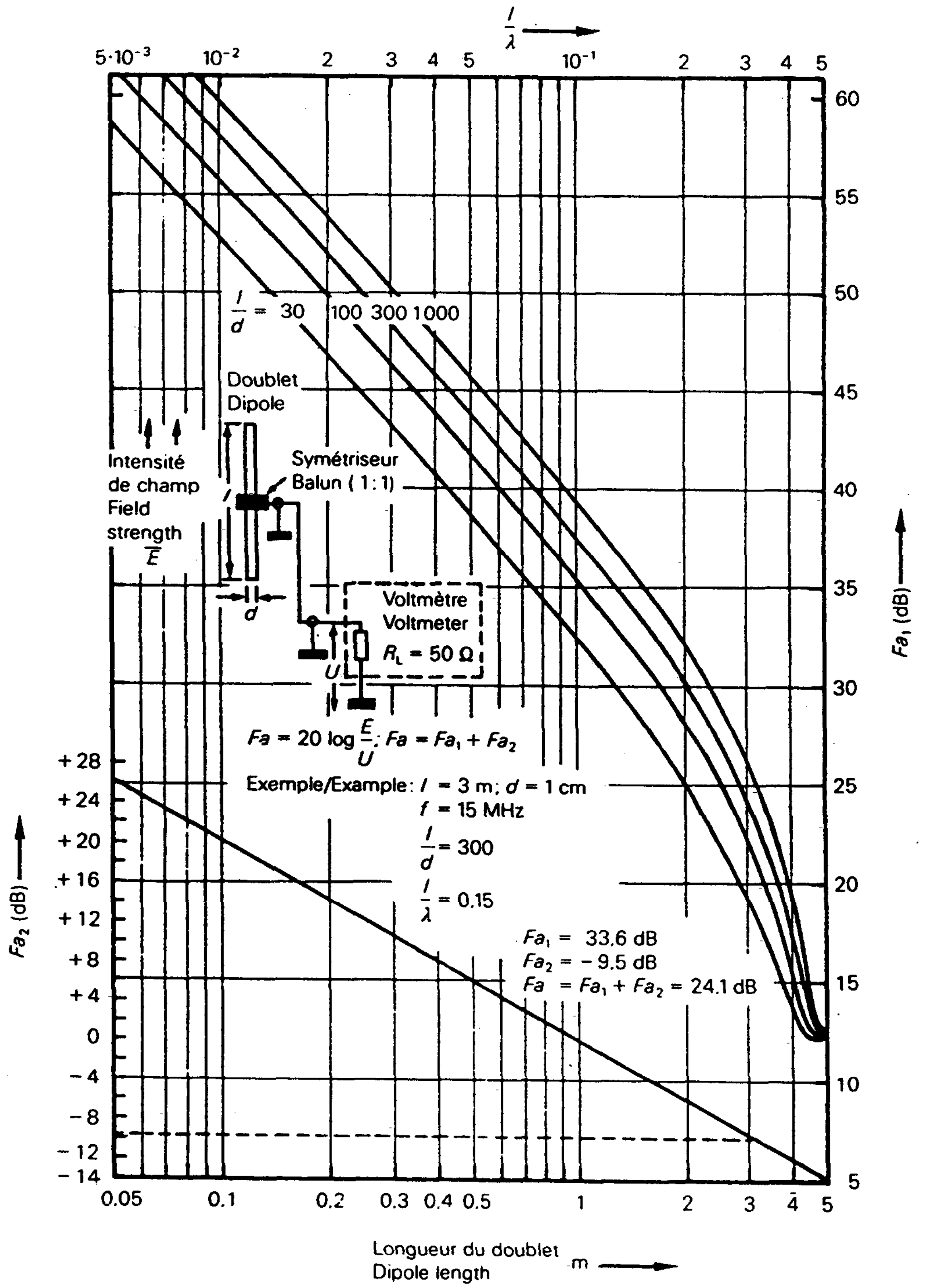


Figure 13 – Short dipole antenna factors for R_L = 50 Ω (subclause 15.4.1.2)

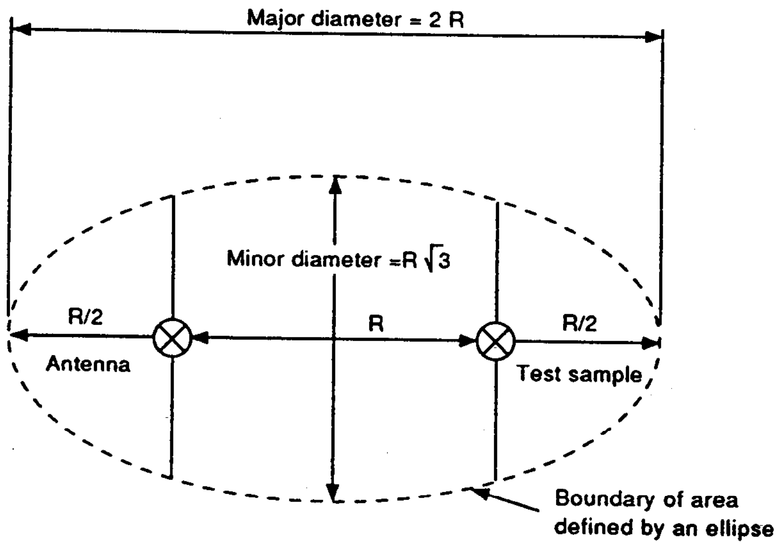


Figure 14 – Obstruction-free area of a test site with a turntable. (Subclause 16.3)

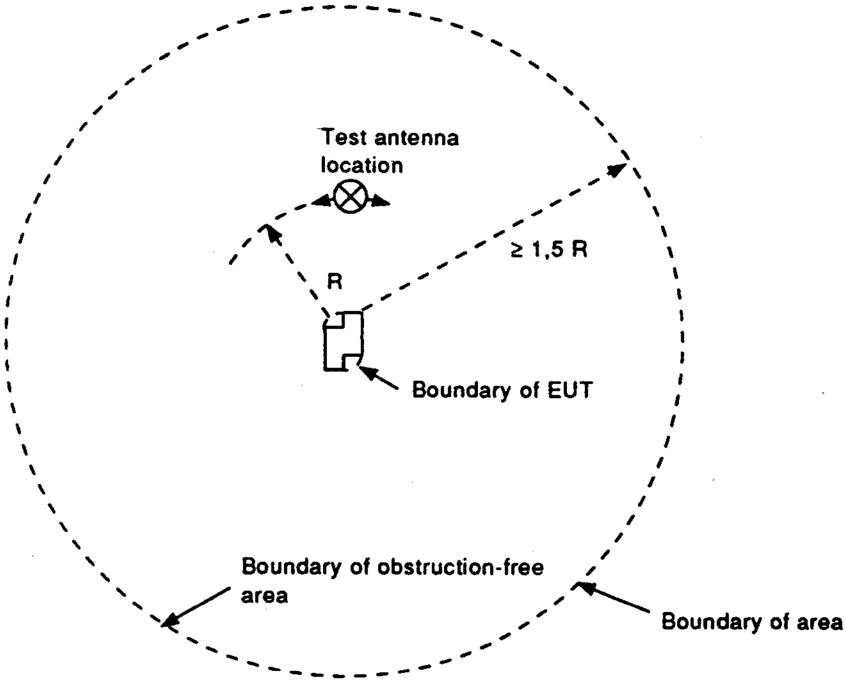


Figure 15 – Obstruction-free area with stationary EUT. (Subclause 16.3)

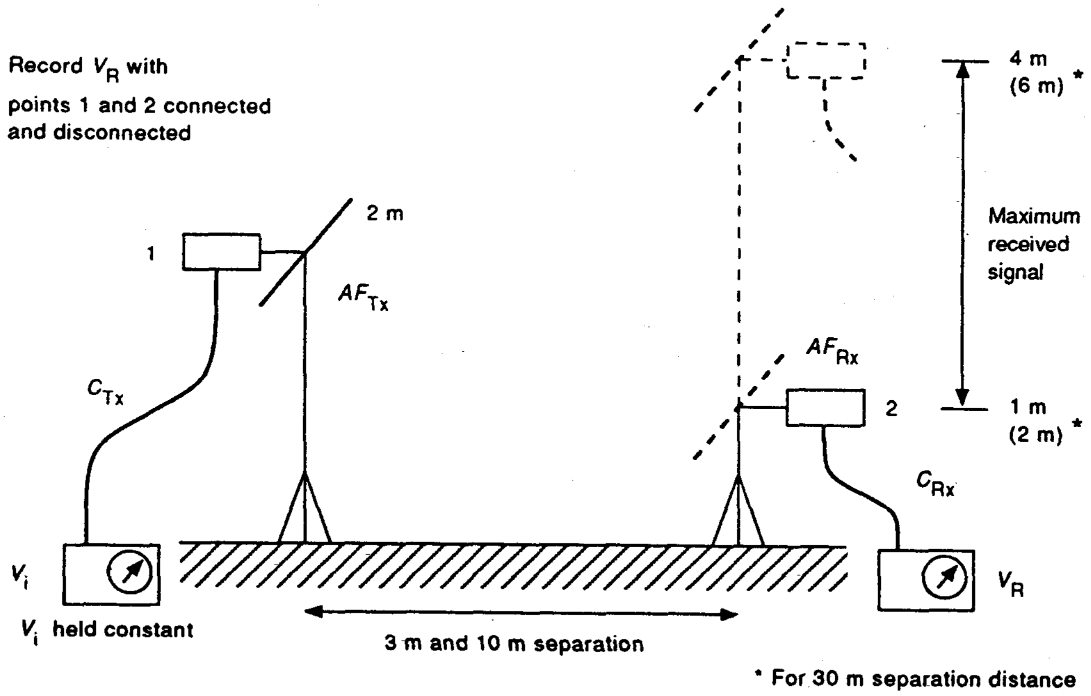


Figure 16 – Configuration of equipment for measuring horizontal polarization of site attenuation. (Subclause 16.6 and annex G)

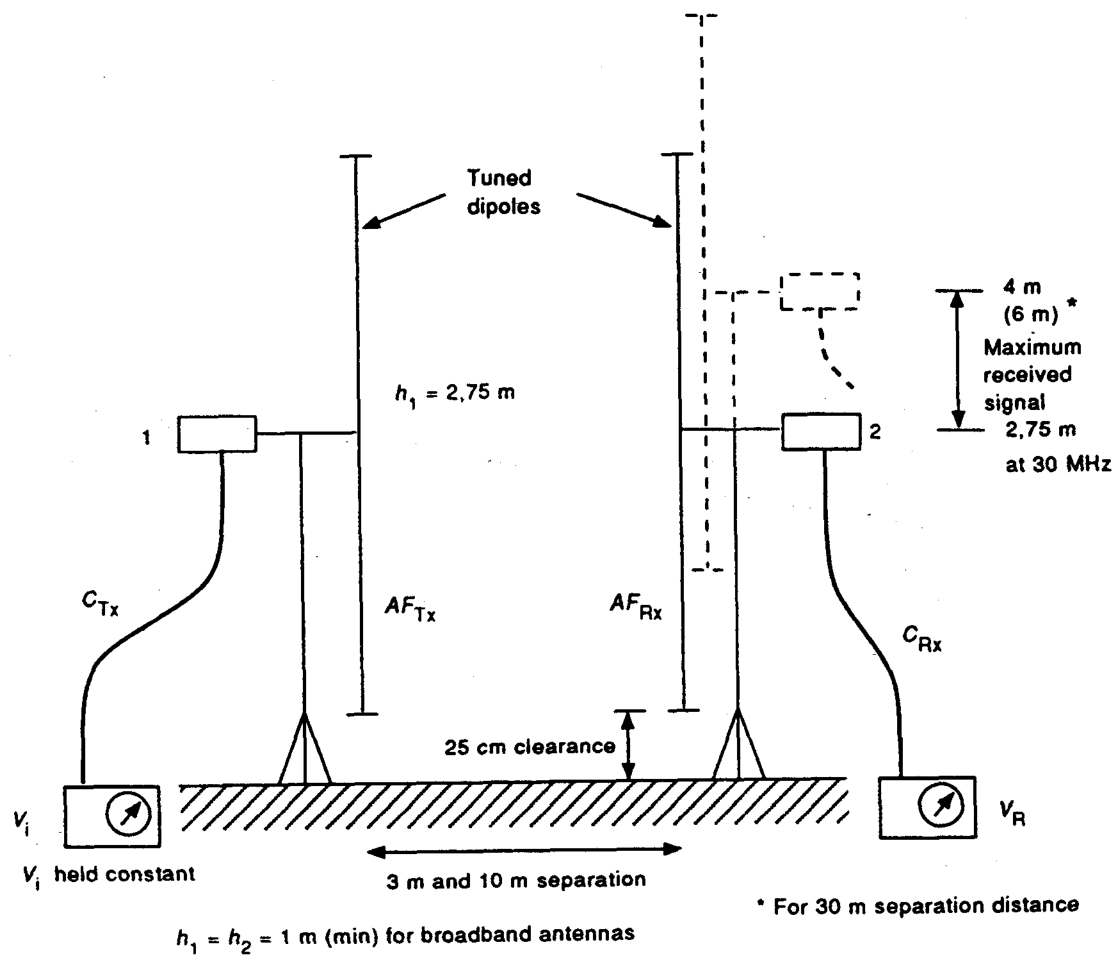
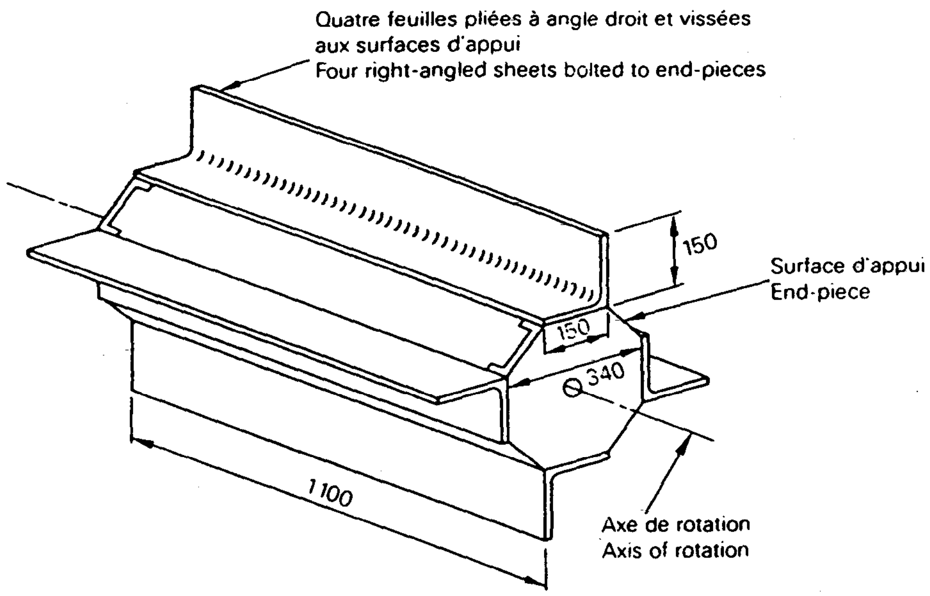
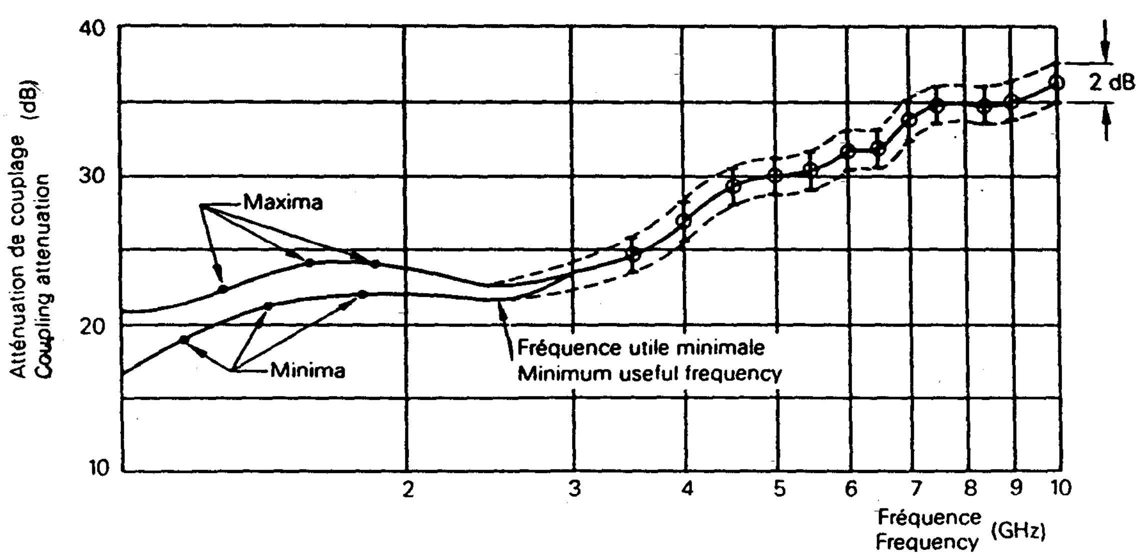


Figure 17 – Configuration of equipment for measuring site attenuation for vertically polarized using tuned dipoles. (Subclause 16.6 and annex G)



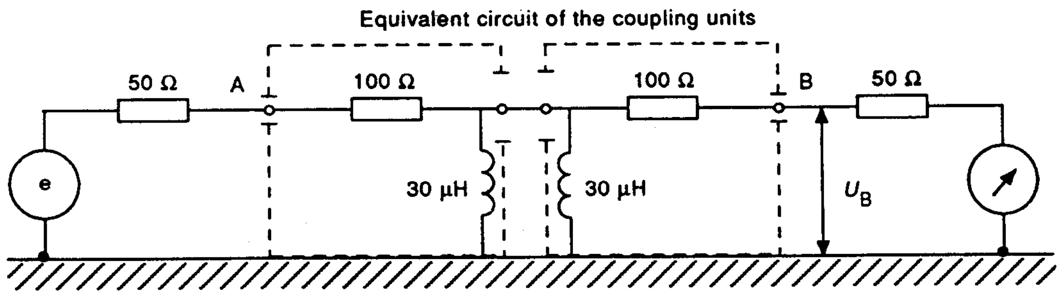
Dimensions in millimetres

Figure 18 – Example of a typical paddle stirrer (subclause 17.1.3.2)



NOTE - All measured points should lie inside the 2 dB envelope marked by dotted line.

Figure 19 – Range of coupling attenuation as a function of frequency for a chamber using the stirrer in figure 18 (subclause 17.1.4)



The insertion loss U_G/U_B of two identical coupling units measured according to this figure should be within 9,6 dB and 12,6 dB in the frequency range 30 MHz to 150 MHz. U_G is the reading of the receiver when the generator and receiver are directly connected together.

NOTE - The two units shall be connected together with very short wires (≤ 1 cm.)

Figure 20 – Measuring set-up to check the insertion loss of the coupling units in the frequency range 30 MHz to 150 MHz (subclause 18.1.2)

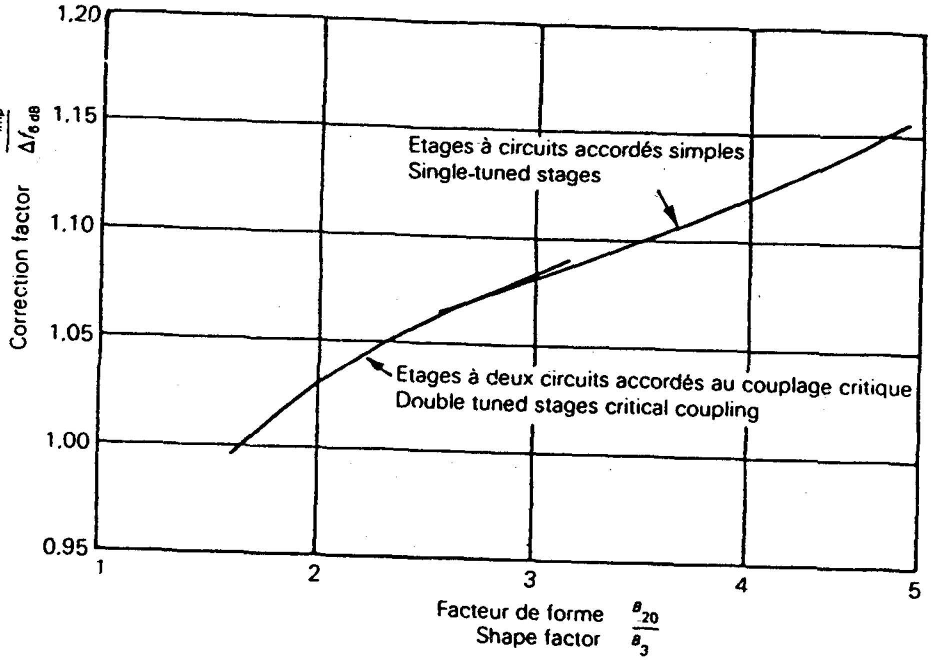


Figure 21 – Correction factor for estimating the ratio B_{imp}/B_6 for other tuned circuits

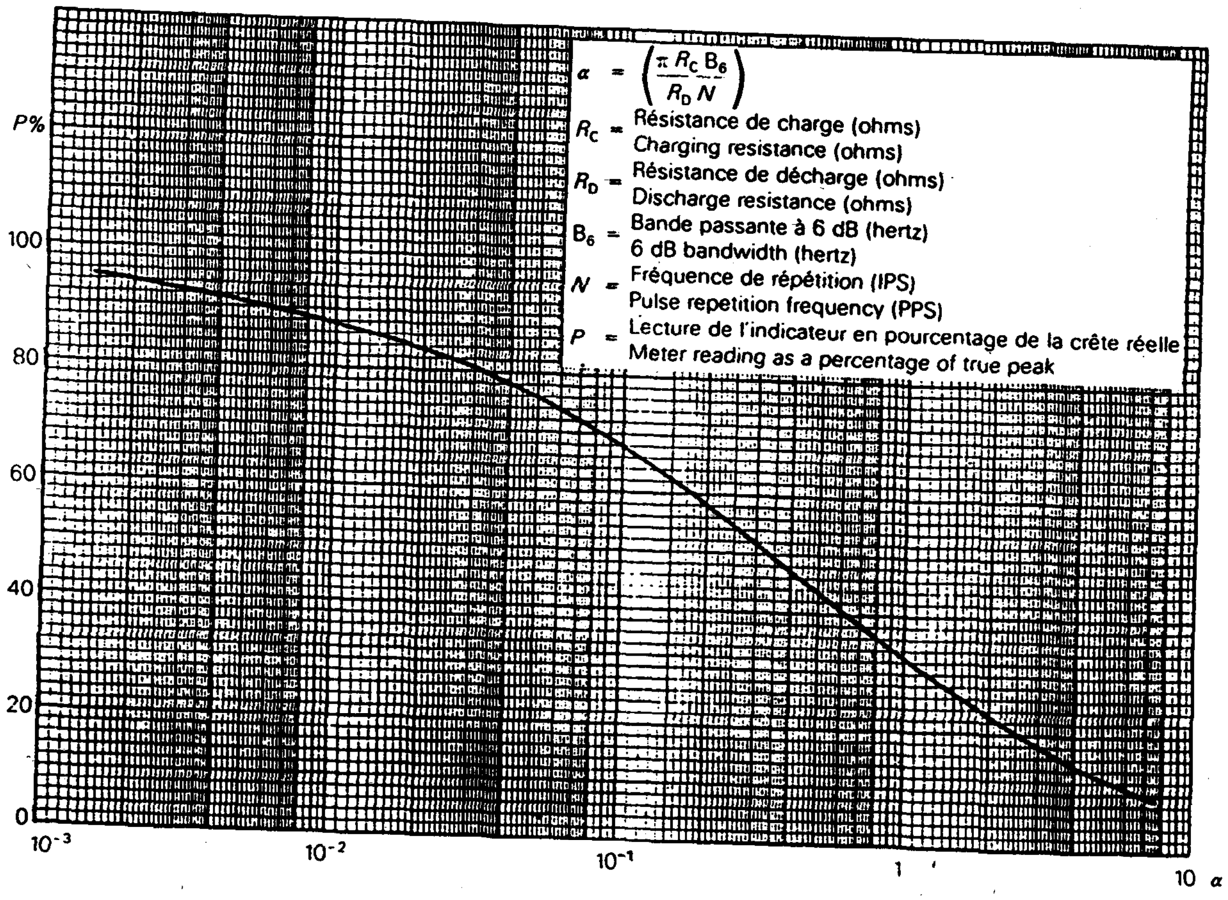


Figure 22 – Pulse rectification coefficient P (annex E, clause E.4)

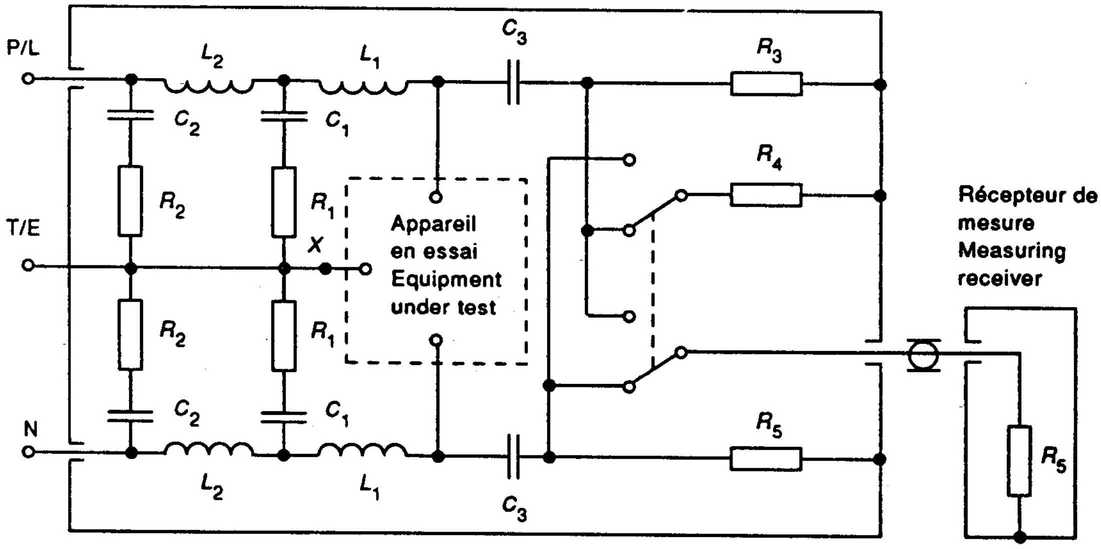


Figure 23 – Example of artificial mains 50 Ω/50 μH + 5 Ω V-network (subclause 11.2 and annex F, clause F.2) (For discussion of *X* see 11.9)

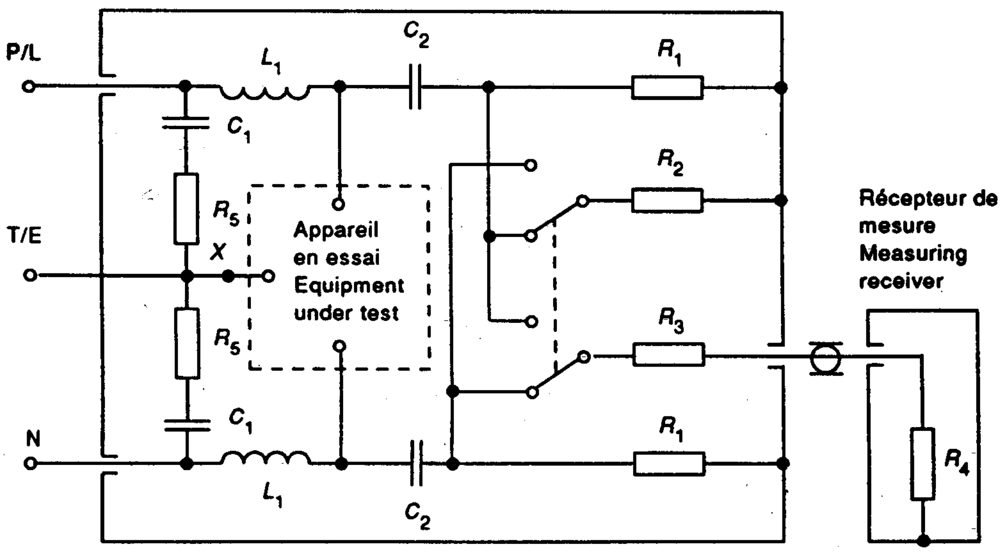
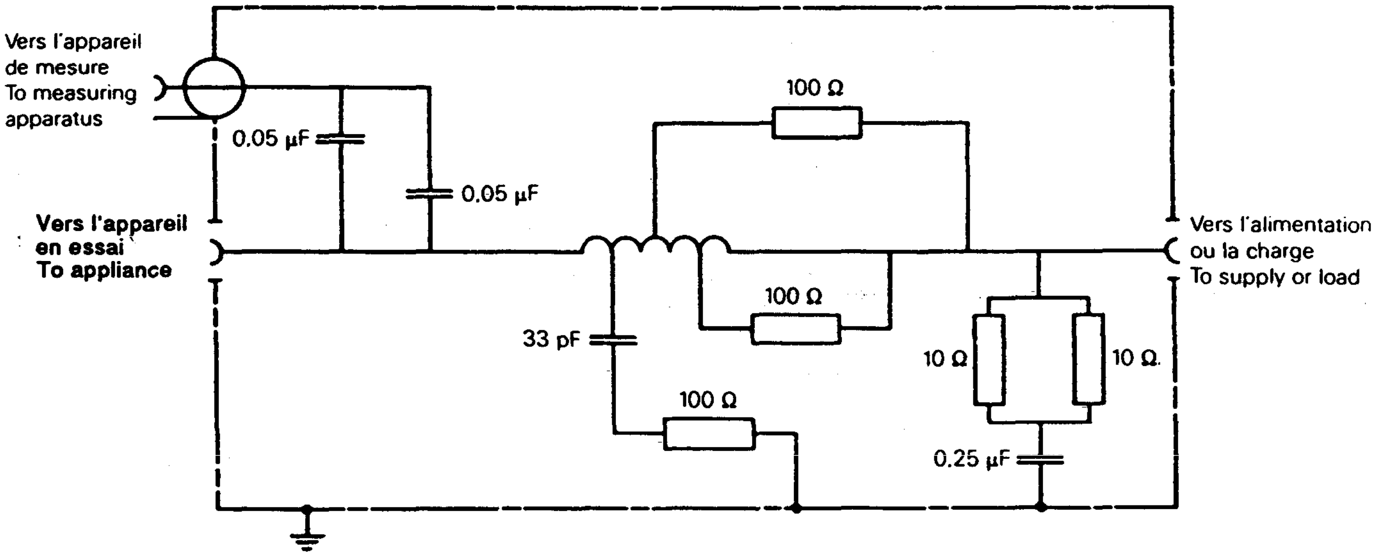
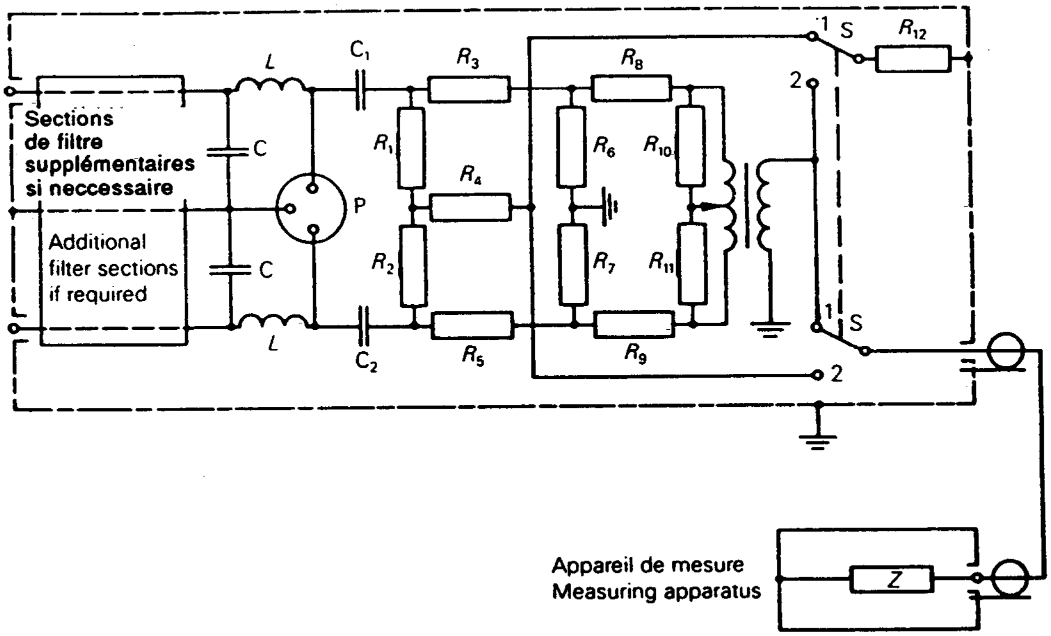


Figure 24 – Example of artificial mains V-networks, 50 Ω/50 μH, 50 Ω/5 μH + 1 Ω or 150 Ω (subclauses 11.3, 11.4, 11.5 and clauses F.3, F.4 and F.5, of annex F respectively)
(For discussion of *X* see 11.9)



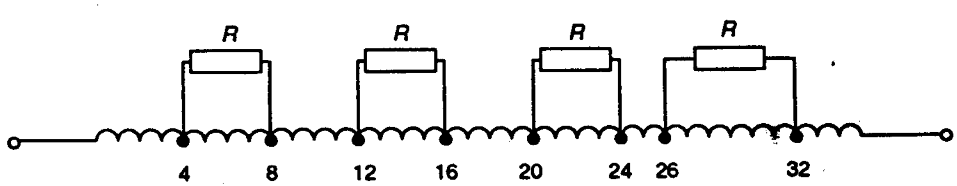
Coil details:
5 µH, 18 turns, Ø 6 mm wound on 50 mm diameter former. Tapping points at 3,5,9 and 13,5 turns.

Figure 25 – Example of an alternative 50 Ω/5 µH + 1 Ω artificial mains network for devices used with low impedance power sources (clause F.4 of Annex F)



P is the connection for apparatus under test
1 for the symmetrical component
2 for the asymmetrical component

Figure 26 – Example of an artificial mains network (delta) for measuring apparatus with unbalanced input (annex F, clause F.6)



Resistors R (430 Ω ± 10 %) are connected to taps at turns 4 and 8, 12 and 16, 20 and 24, 26 and 32. Inductance is 50 µH ± 10 %.

Figure 27 – Schematic of 50 µH inductor (annex F, clause F.7.1)

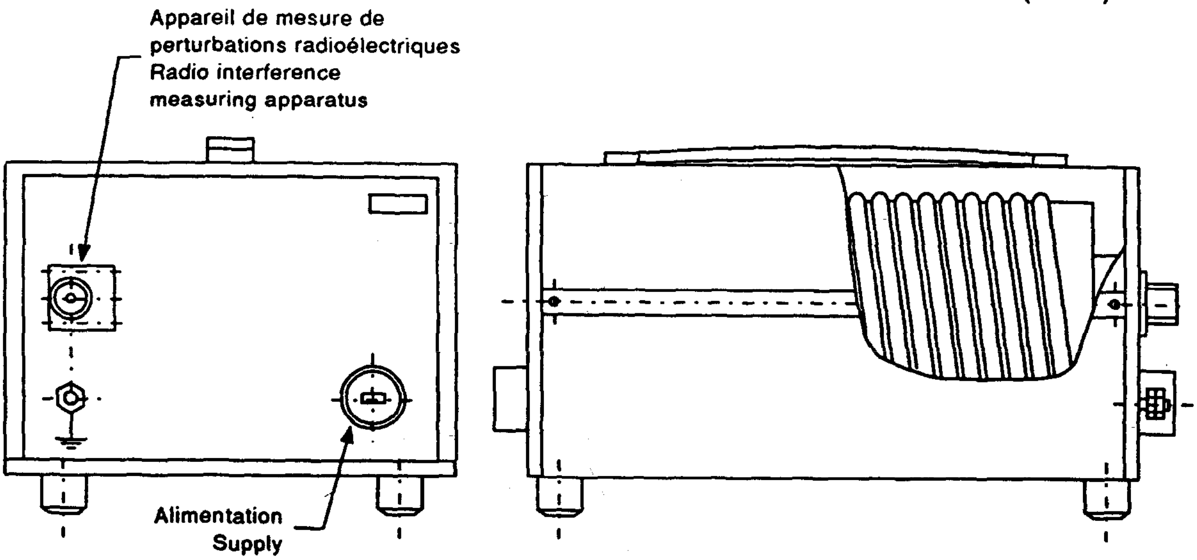
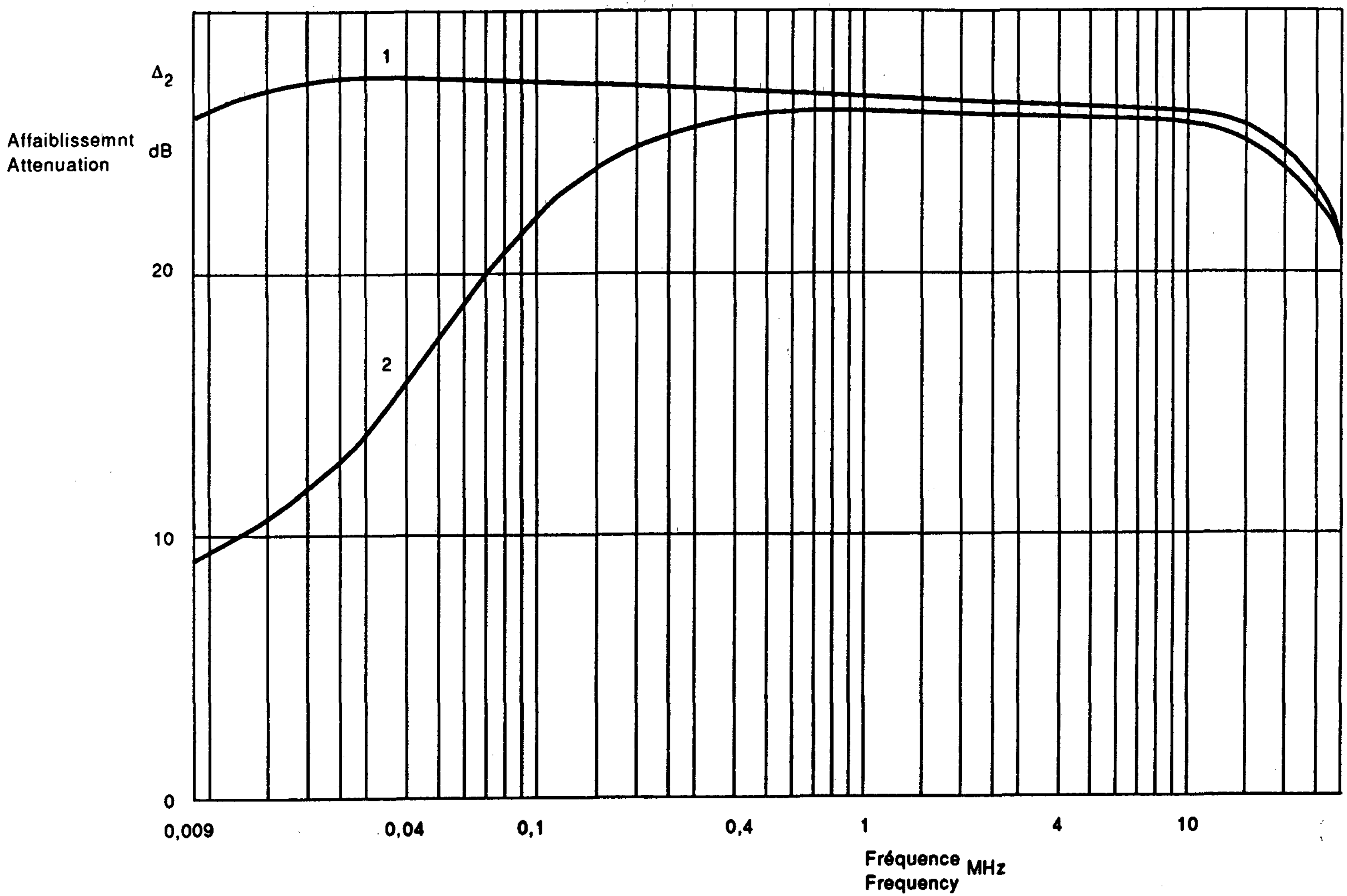


Figure 28 – A general view of the artificial mains network (annex F, clause F.7.2)



1 - Z_{gen} R_{gen} = 50 Ω

2 - Z_{gen} $|Z_{in\ AMN}|$

Figure 29 – Attenuation of an artificial mains network filter (Annex F, clause F.7.3)

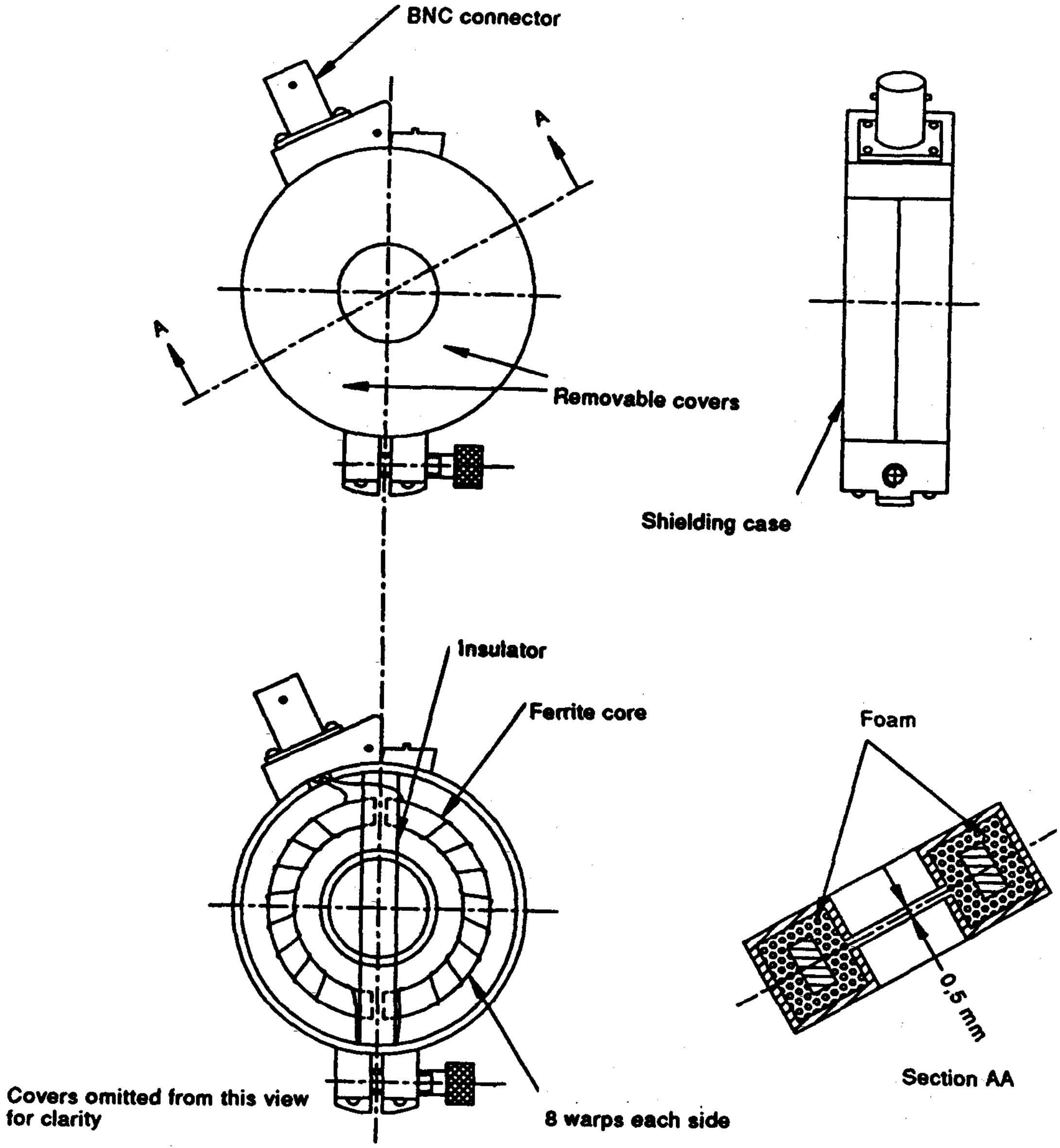


Figure 30 – Typical current probe configuration (annex J, clause J.1)

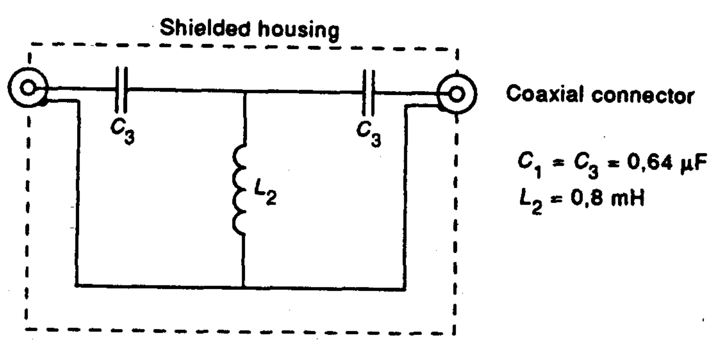
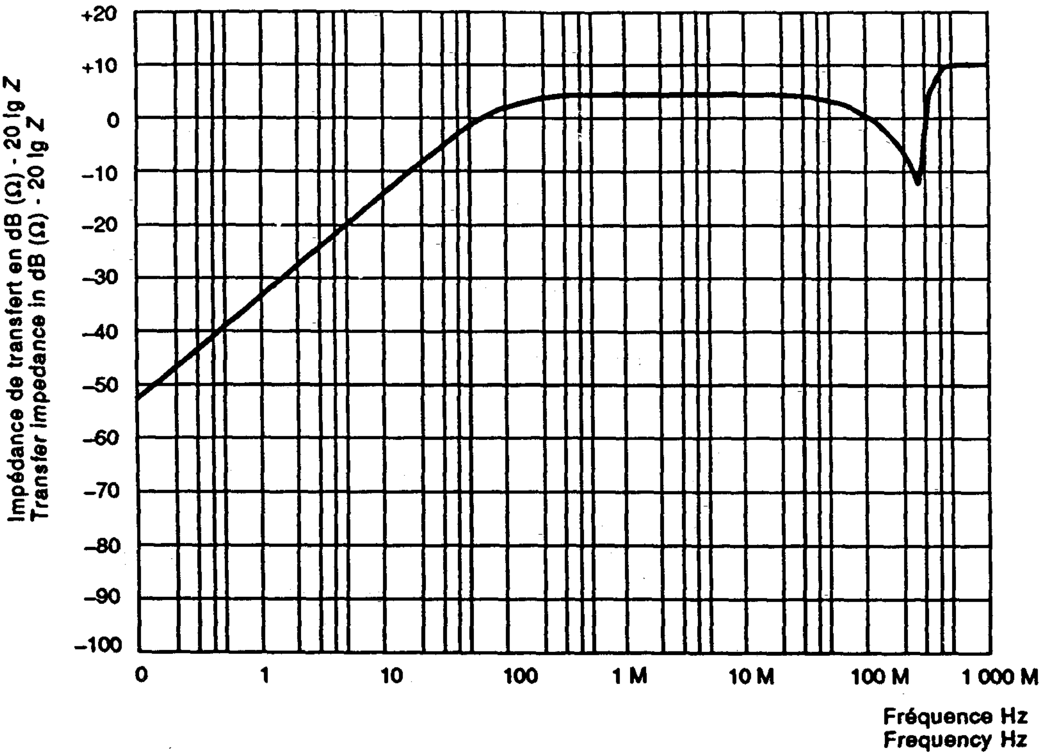
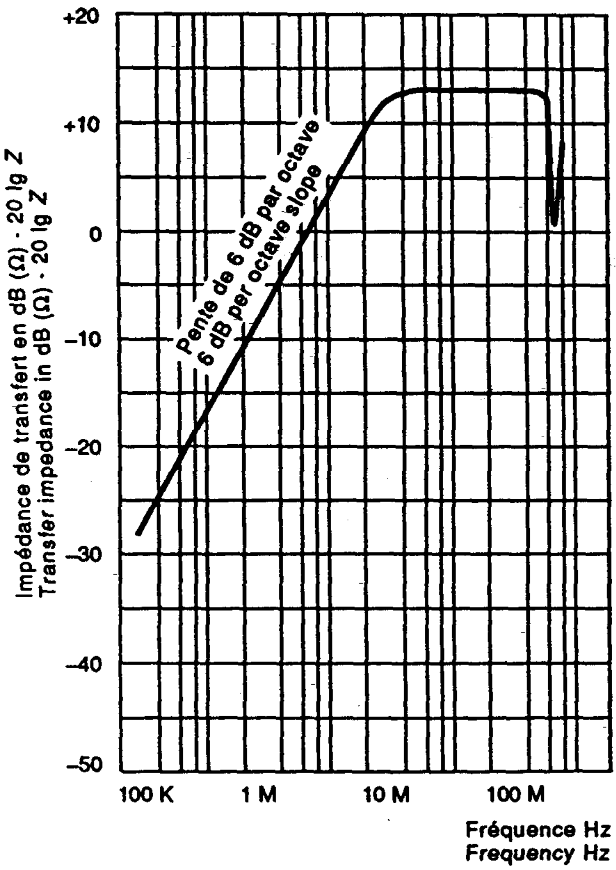


Figure 31 – High-pass filter with cut-off frequency of 9 kHz (annex J, clause J.3, J.5.3)





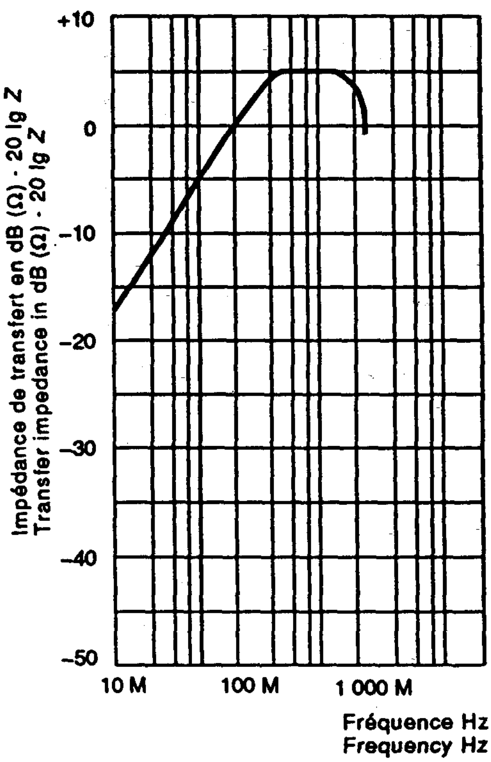


Figure 32 – Transfer impedance of typical current probes (annex J, clause J.4)

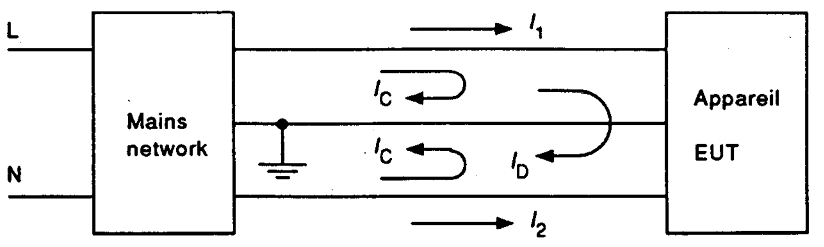


Figure 33a – CISPR test circuit with interference currents (annex J, clause J.5.1)

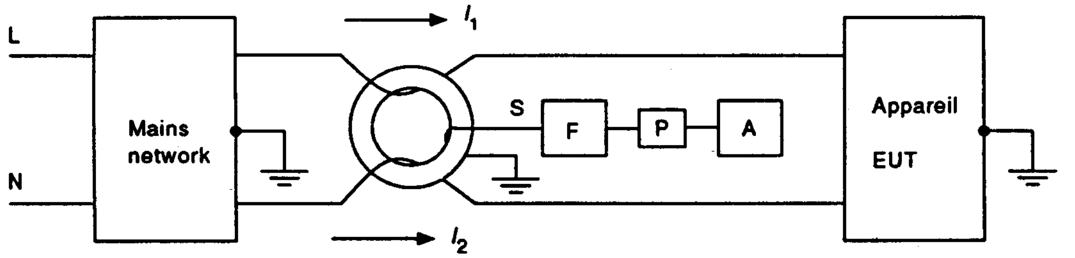
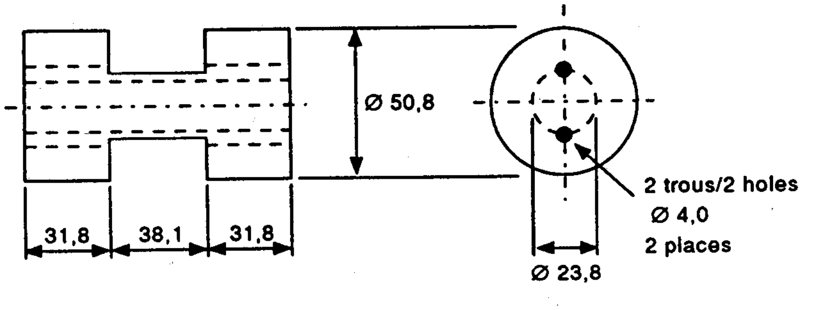


Figure 33b – Test circuit which differentiates common (asymmetrical) mode and differential (symmetrical) mode noise (annex J, clause J.5.1)



Dimensions in millimetres

Figure 34 – Shield configuration used with current transformer (annex J, J.5.2) (The material should be highly conductive, e.g. copper or brass)

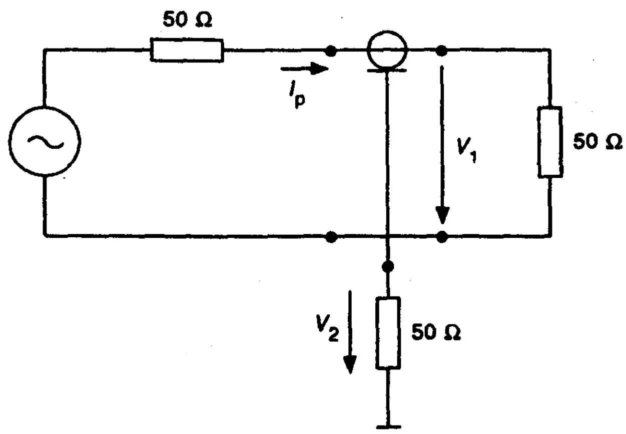


Figure 35 - Schematic diagram of circuit with coaxial adapter and current probe (annex J, clause J.6)

Mesure du facteur k de la sonde de courant
Current probe factor k measurement

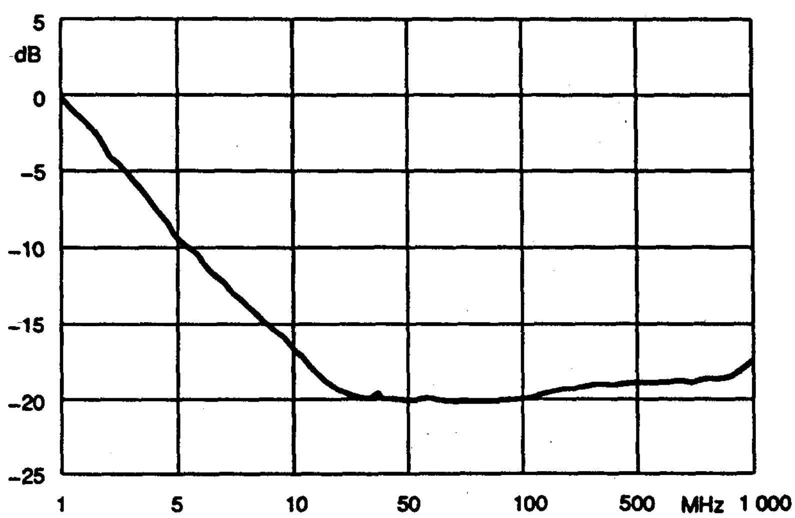
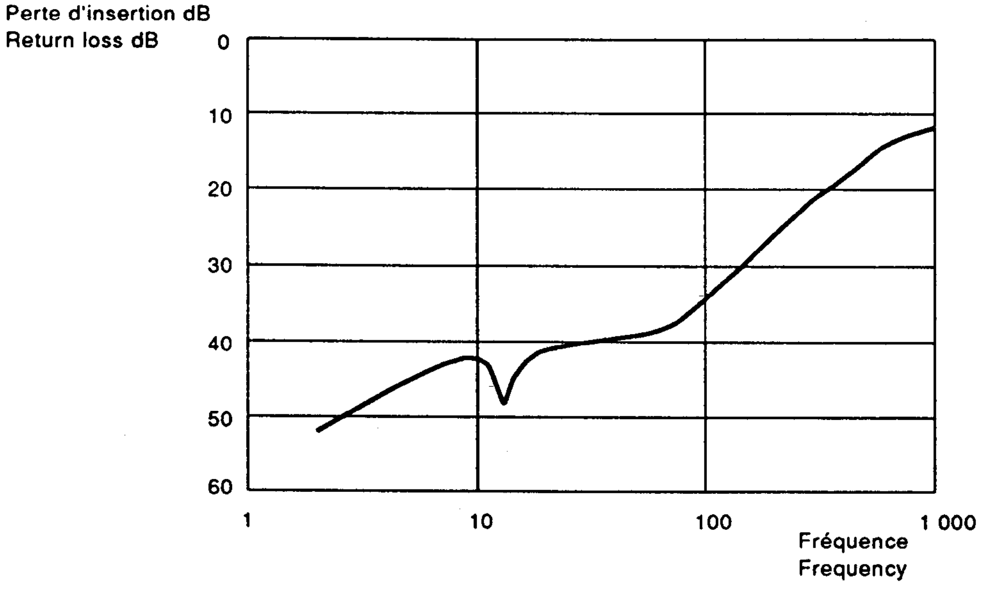


Figure 36 - Current probe factor k as a function of frequency (annex J, clause J.6)



Return loss of the coaxial adapter (see below) terminated with 50 Ω and with the current probe inside. The current probe is also terminated with 50 Ω.

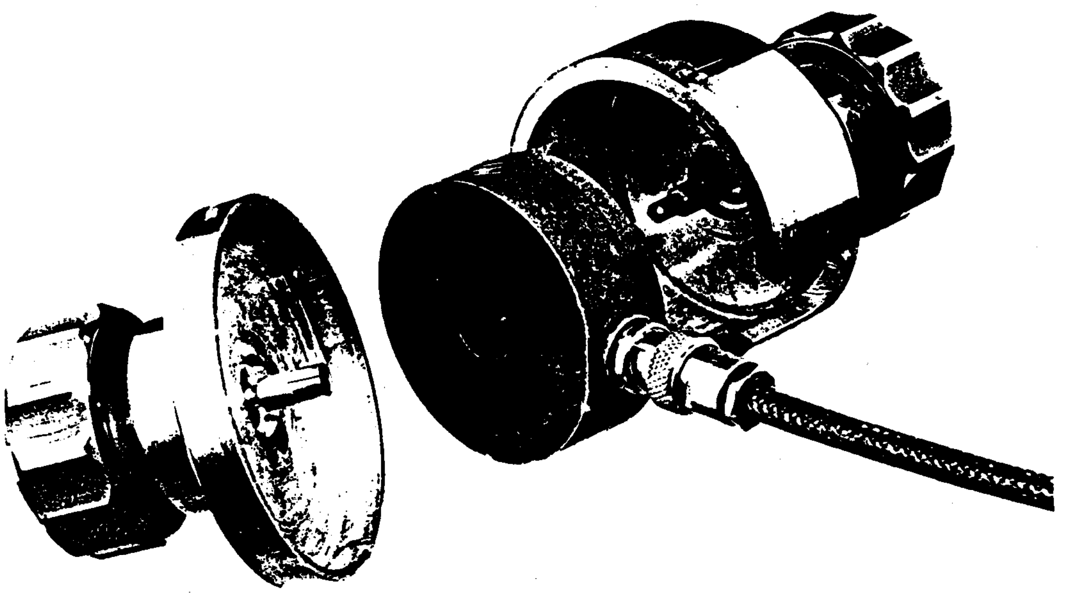
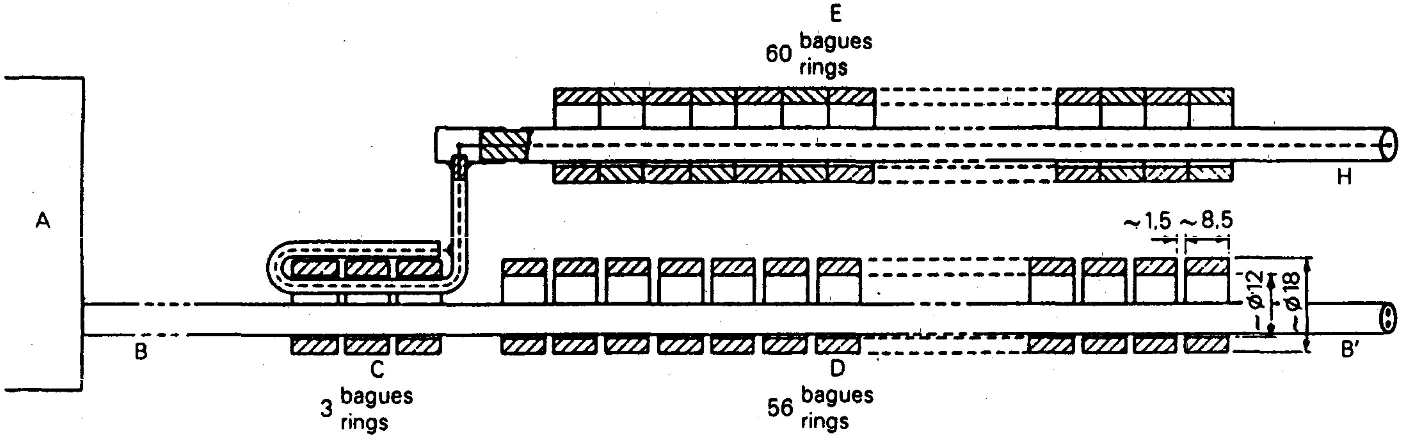


Figure 37 – Current probe between the two halves of the coaxial adapter (annex J, clause J.6)

A is the equipment under test
B is the lead under test
C is the current transformer
D is the absorbing section
E is the absorbing section on cable from transformer



Dimensions in millimetres

Figure 38 – Example ot the construction of an absorbing clamp (annex K)

B is the lead under test
C is the current transformer
D is the absorbing section
E is the absorbing section on cable from transformer
1 is the metal cylinder-two halves
2 is the centralising tube for lead B
3 is the coaxial connector

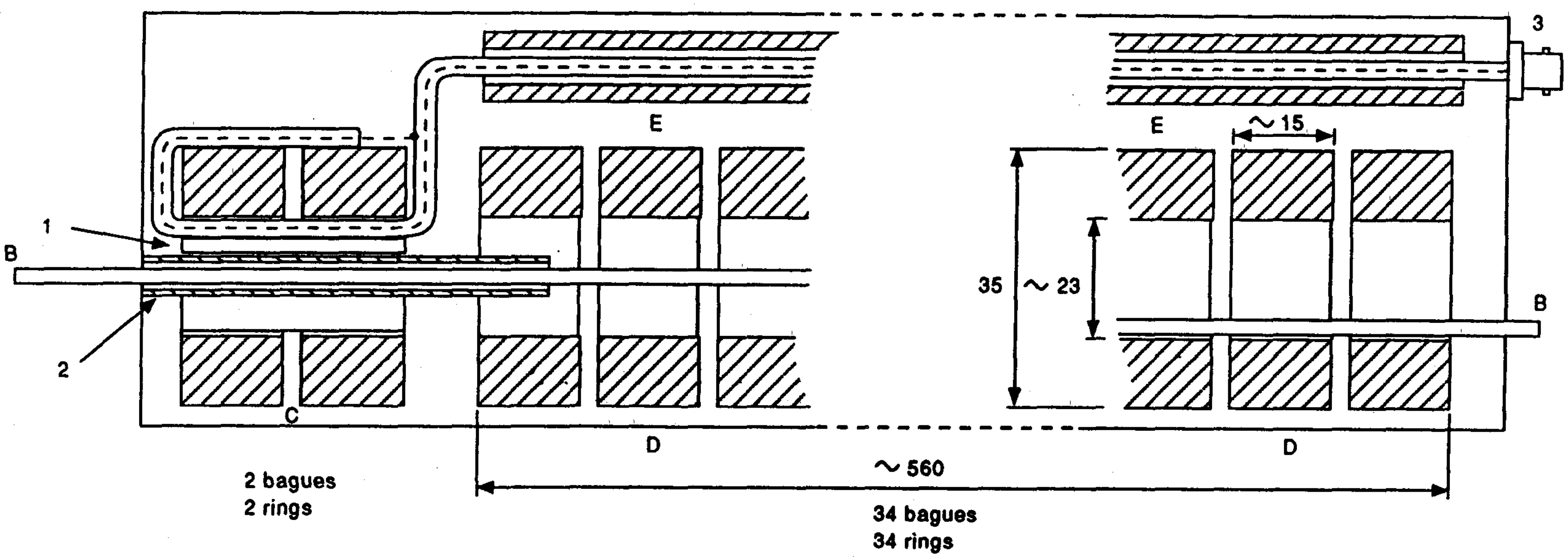


Figure 39 – Example of the construction of an absorbing clamp with additional features (annex K)

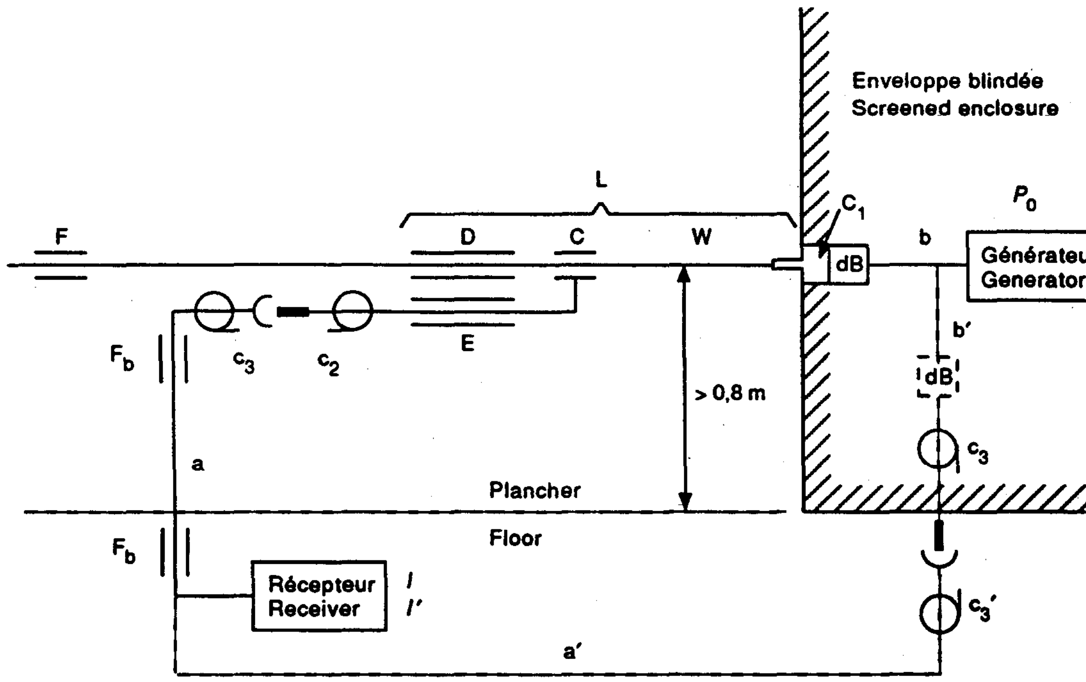


Figure 40 – Arrangement for calibration of the absorbing clamp (annex H and subclause 13.3)

W	is the wire for calibration
C, D, E	are the parts of the absorbing clamp (see also figure 39)
F	is the additional absorber for $f < 50$ MHz
c_1	is the coaxial connector for calibration wire W.
c_2	is the coaxial connector on internal coaxial cable of clamp
c_3	is the coaxial connector mating c_2, on cable to receiver
a	is the coaxial cable from absorbing clamp to the receiver
b	is the coaxial cable from generator to attenuator, attenuation
Att.	is the attenuator pad, minimum 10 dB attenuation
c_3', a', b', att'	are different positions of C_3, a, b and att., respectively when aligning generator and receiver readings including attenuation of coaxial cables and attenuator
L	is the insertion loss of absorbing clamp with wire, in position for maximum indication
P_0	is the constant output of generator over a 50 Ω load
I	is the maximum indication on receiver when connected to the clamp
I'	is the indication on measuring receiver when connected to generator via attenuator and coaxial cables (dotted lines)
F_b	is the ferrite absorbing rings or sleeve

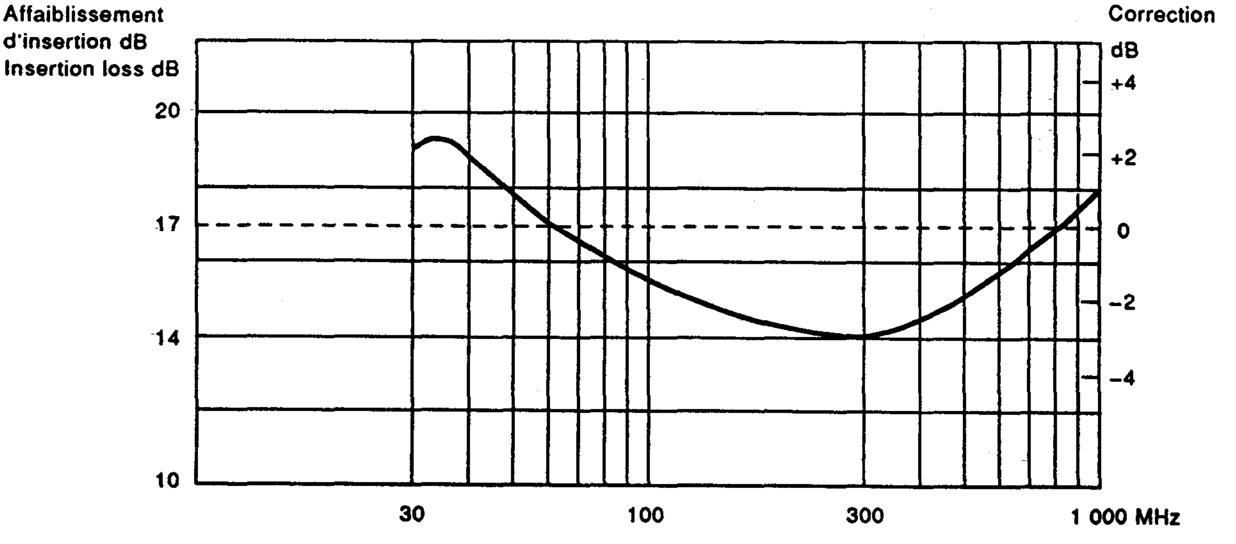
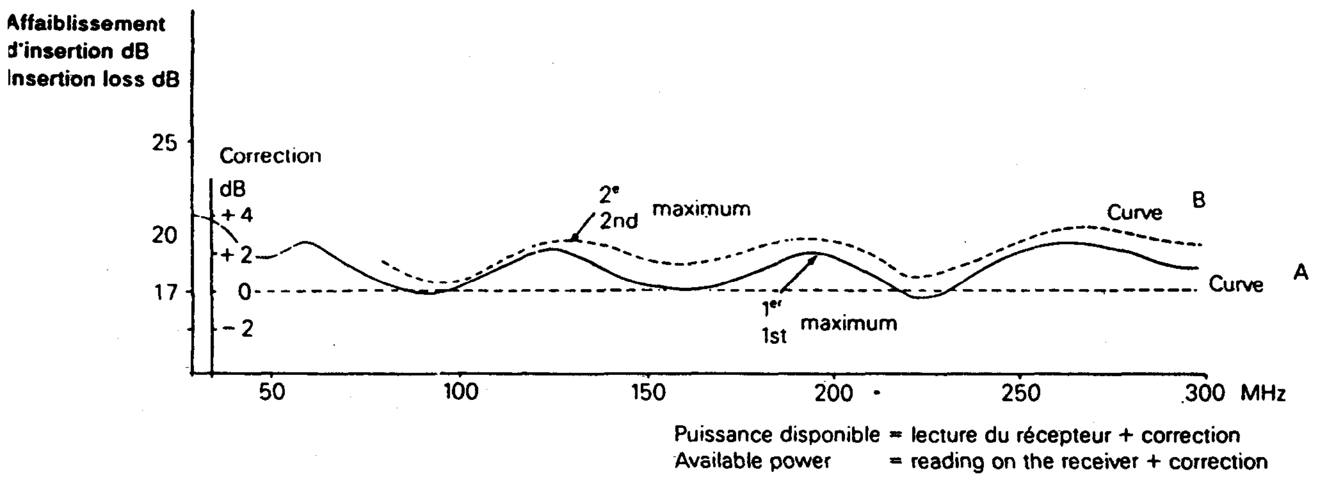


Figure 41 – Example of calibration curve of the absorbing clamp (annex H)



Puissance disponible = lecture du récepteur + correction
Available power = reading on the receiver + correction

Figure 42 – Calibration of the absorbing clamp (annex H)

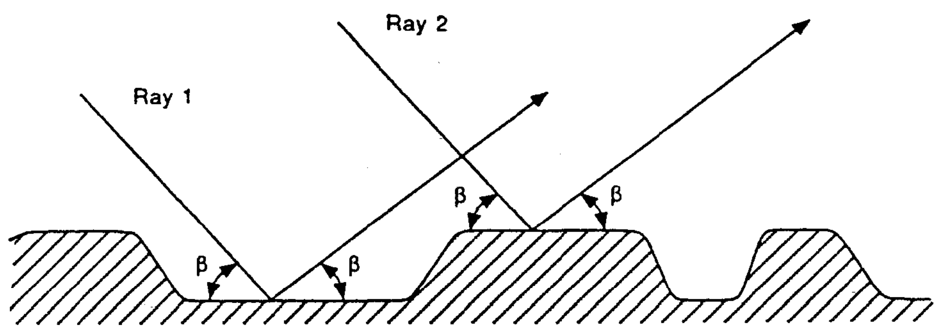
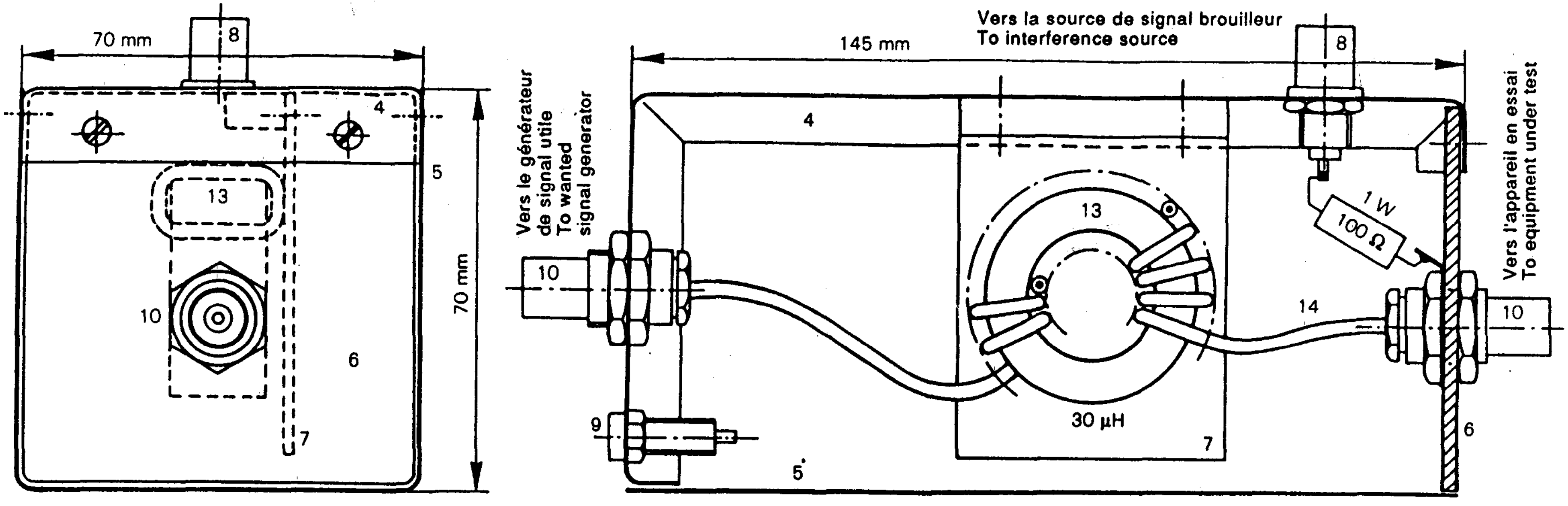


Figure 43 – The Rayleigh criterion for roughness in the ground plane (annex L, clause L.2.2)

Measurement distance R m	Source height, h_1 m	Maximum receiving antenna height, h_2 m	Maximum RMS roughness b	
			In wavelengths	At 1 000 MHz cm
3	1	4	0,15	4,5
10	1	4	0,28	8,4
30	2	6	0,49	14,7

The values of b are calculated according to the formula:

$$b = \frac{\lambda}{8 \sin \beta}$$



4-5 is the metallic case 145 mm x 70 mm x 70 mm (parts 5 placed on the ground plane P1)
6 is the front plate (insulating material)
7 is the supporting plate for chokes (insulating material)
8 is a coaxial connector, BNC, 50 Ω
9 is the ground jack
10 is a coaxial connector, BNC

13 is a ferrite ring type 4C6, Ø 36 mm x Ø 23 mm x 15 mm with 14 turns of coaxial cable
14 is a coaxial cable, outer Ø 2,4 mm

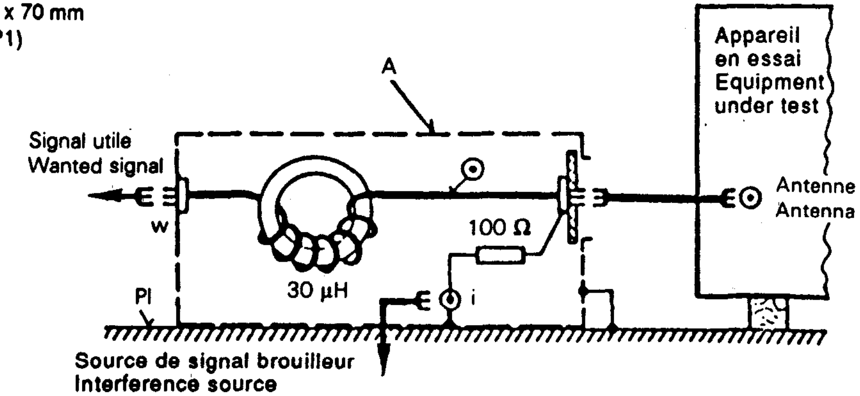
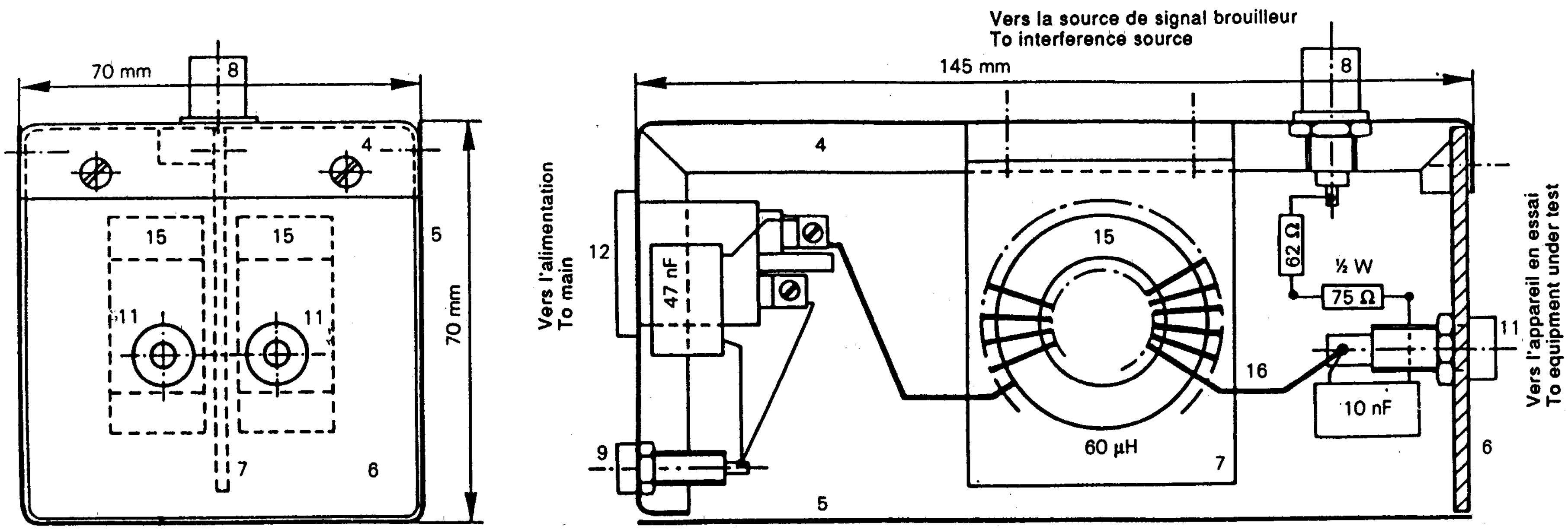
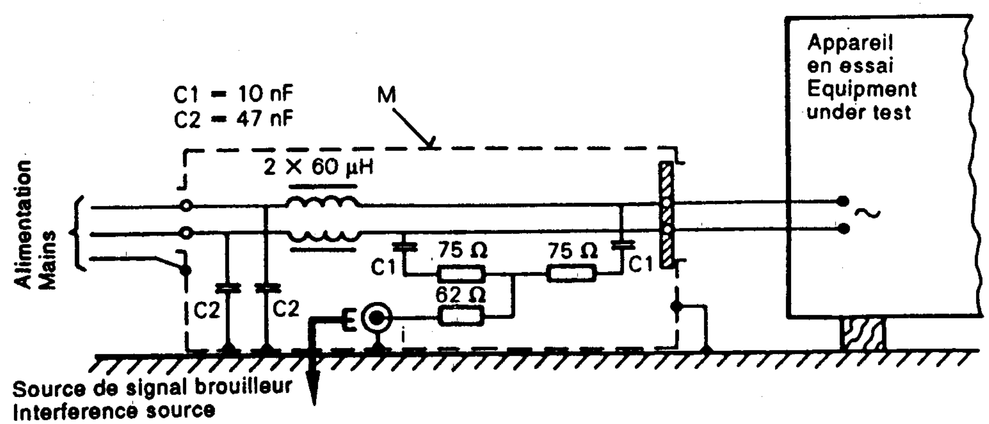


Figure 44 - Example of coupling unit type A, for coaxial input. Schematic diagram and construction details (annex N, clause N.1 and annex P, clause P.2)





Part 4 to 9: see unit type A

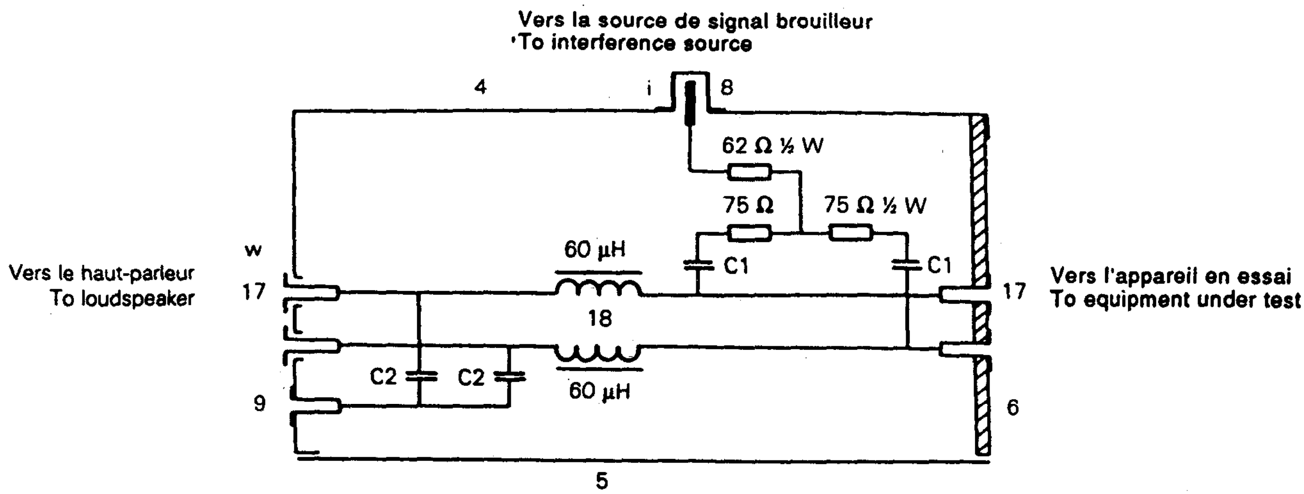
11 is the mains socket for equipment under test (two insulated banana jacks)

12 is the mains plug (2P + ground)

15 are two ferrite rings type 4C6, Ø 36 mm x Ø 23 mm x 15 mm, with 20 turns each

16 is a 0,8 mm copper wire insulated, outer Ø 0,8 mm

Figure 45 – Example of coupling unit type M, for mains leads. Schematic diagram and construction details (annex N, clause N.2 and annex P, clause P.2)



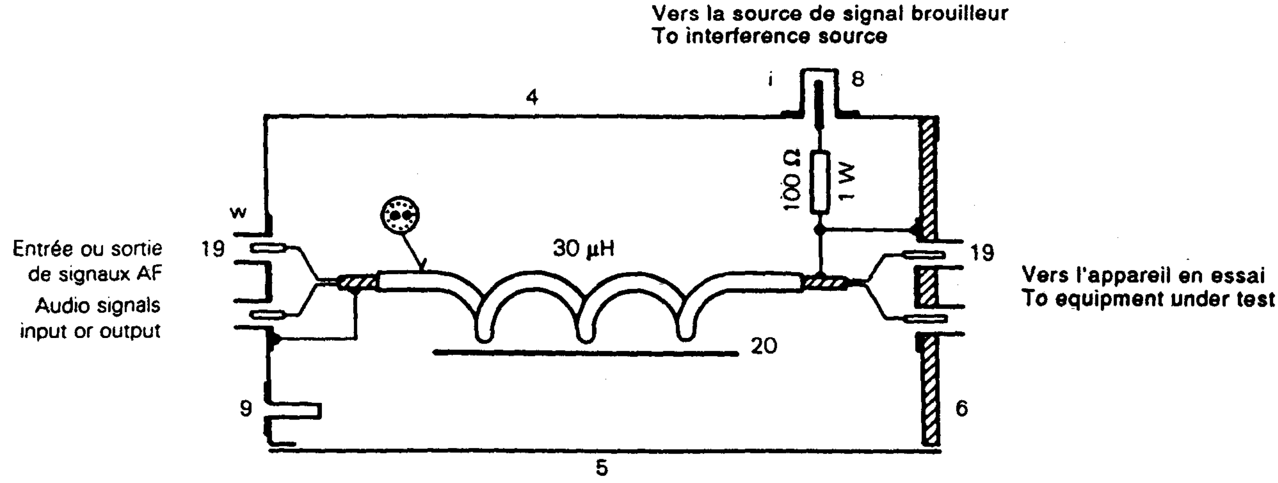
Parts 4-5-6-8-9: see unit type A.

17 are insulated banana jacks

18 are two inductances, 60 µH each. For each inductance:
Core: one ferrite ring, type 4C6,
Ø 36 mm x Ø 23 mm x 15 mm
Winding: 20 turns. Copper wire insulated
outer Ø 1,2 mm
Mounting of the inductances: see unit type M

C1 = 10 nF
C2 = 47 nF

Figure 46 – Example of coupling unit type L for loudspeaker leads. Schematic diagram and simplified construction drawing (annex N, clause N.3 and annex P, clause P.2)

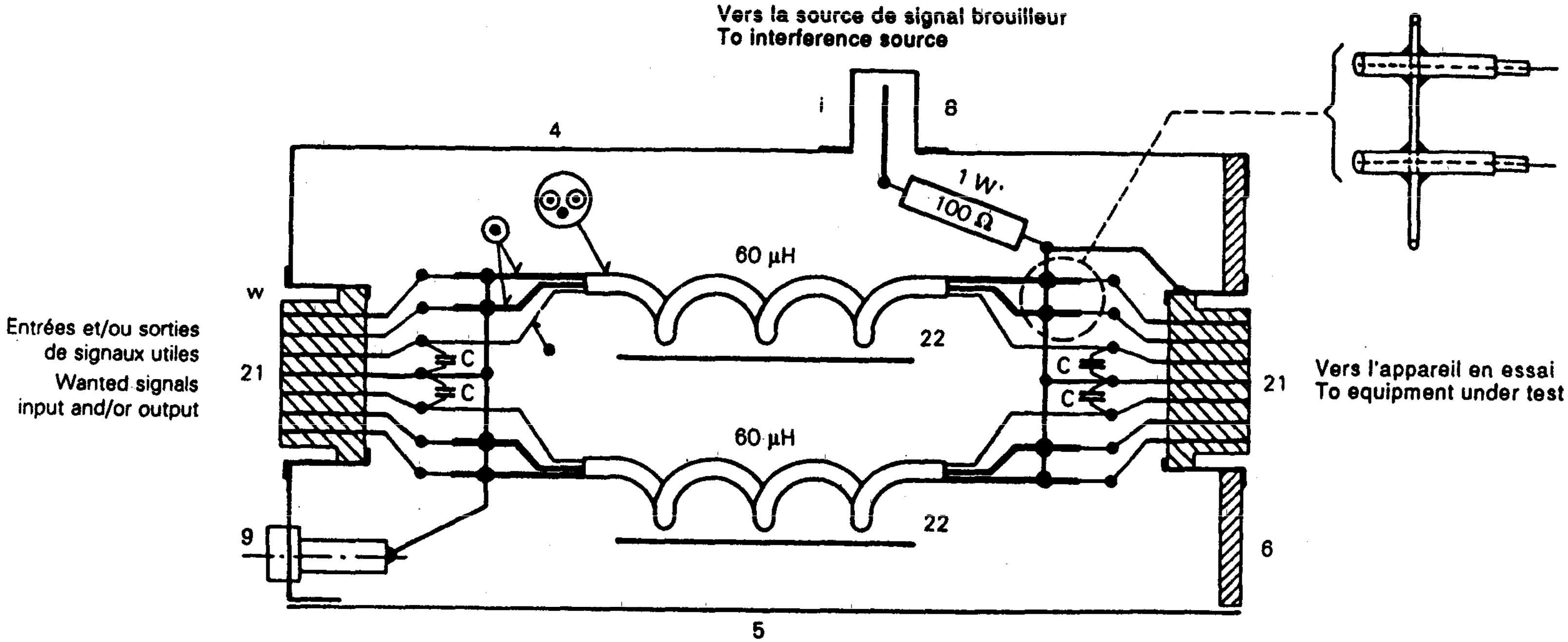


Parts 4-5-6-8-9: see unit type A.

19 are Cinch or DIN sockets

20 is the inductance 30 µH:
Core: one ferrite ring, type 4C6,
Ø 36 mm x Ø 23 mm x 15 mm
Winding: 14 turns with a screened twisted pair:
outer diameter of cable insulation 2,8 mm
Mounting of the inductance: see unit type A

Figure 47 – Example of coupling unit type Sw, for audio signals. Schematic diagram and simplified construction drawing (see annex N, clause N4 and annex P, clause P.2)



Parts 4-5-6-8-9: see unit type A.

21 are multiple pins connector
(e.g. 7 pins DIN-socket)

22 are two inductances, 60 µH each. For each inductance:
Core: one ferrite ring, type 4C6,
Ø 36 mm x Ø 23 mm x 15 mm
Winding: 20 turns with a three lead cable:
Cable: two micro-coaxial cables, UT-34, outer Ø 0,9 mm
+ one copper wire, Ø 0,4 mm, varnish insulated;
outer insulation: tube outer Ø 2,4 mm.
Mounting of the inductances: see unit type M
C = 1 nF (or more, if it is acceptable by the signal source)

Figure 48 – Example of coupling unit type Sw, for audio, video and control signals.
Schematic diagram and simplified construction drawing. (Annex N, clause N.5 and annex P, clause P.2)

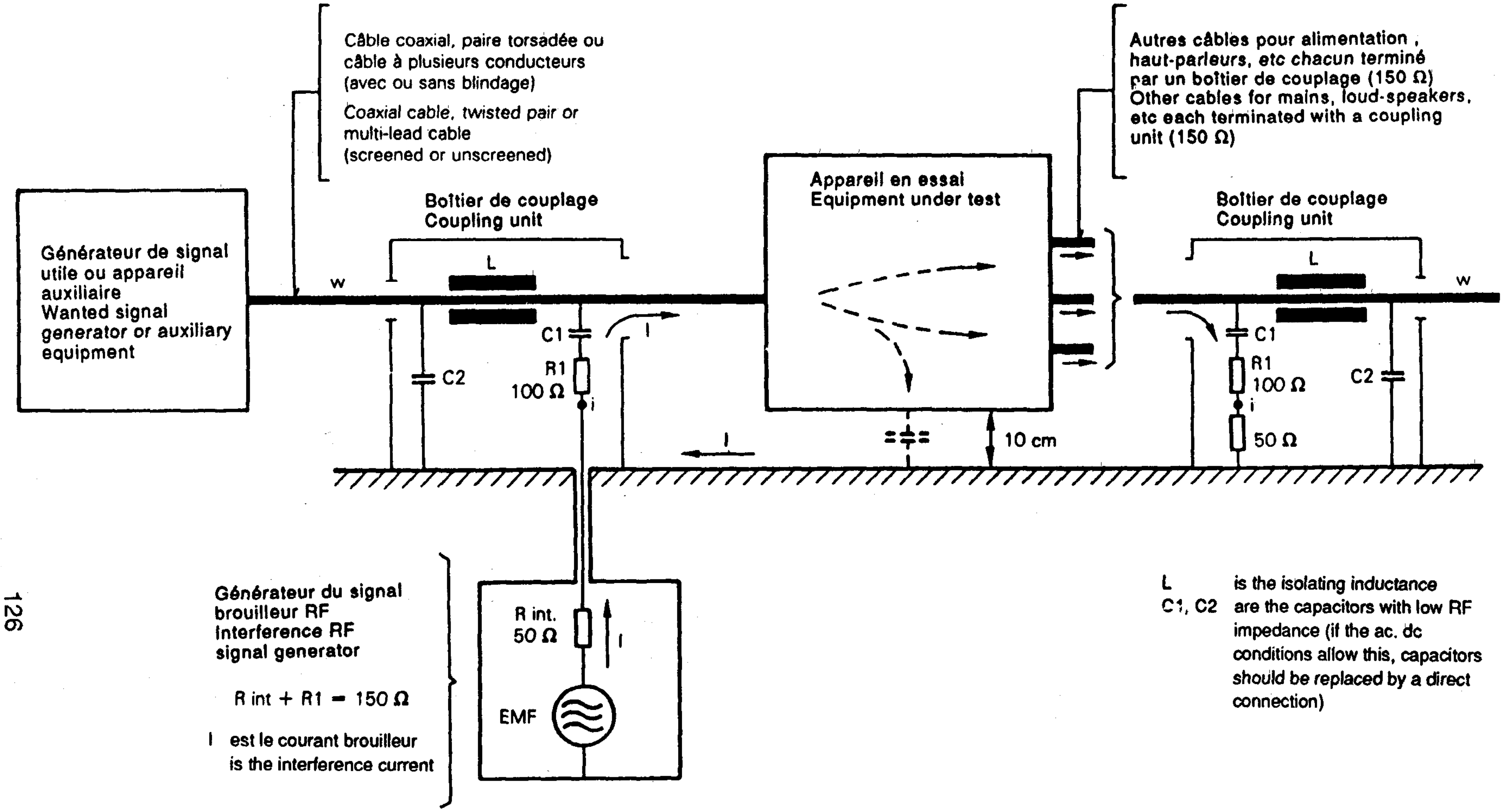
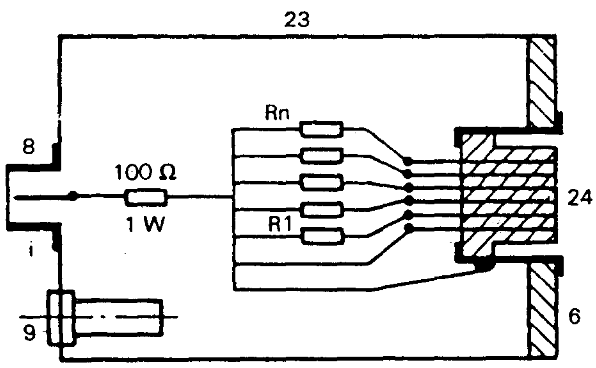


Figure 49 – General principle of the current-injection method (annex P, clause P.1)



Parts 6-8-9: see unit type A.

23 is the metallic case 100 mm x 55 mm x 55 mm

24 is the multiple-pin connector or DIN-socket

R1 to Rn are the matched load resistances

Examples: Coupling units Sr for audio equipment:

Phonograph { magnetic: 2 x 2,2 kΩ
crystal: 2 x 470 kΩ

Microphone:	2 x 600 Ω
Turner:	2 x 47 kΩ
Tape recorder:	4 x 47 kΩ
Audio in/out:	4 x 47 kΩ

Figure 50 – Coupling unit type Sr with load resistances.
Schematic diagram and simplified construction drawing
(annex P, clause P.2)

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AMENDMENT NO. 1

Page 11

2.8 Screening effectiveness

Replace the text of this subclause by the following:

2.8.1 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 1.3.11.

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

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

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

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

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

2.8.2 Limitation of radio-frequency emissions from the measuring receiver

2.8.2.1 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.

2.8.2.2 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 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).

Page 32

15 Antennas for measurement of radiated radio disturbance

Add the following text at the end of the introductory paragraph:

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

Page 33

15.2.1 Magnetic antenna

Add, after the existing text, the following new text:

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

The unit of the magnetic field strength is μA/m or, in logarithmic units, 20 log(μA/m) = dB (μA/m). The associated emission limit shall be expressed in the same units.

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

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

To obtain the reading of H(μA/m), the reading E(μV/m) is divided by 377 Ω:

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

To obtain the reading of H dB(μA/m), 51,5 dB(Ω) is subtracted from the reading E (dB(μV/m)):

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

The impedance Z = 377 Ω, with 20 $\log_{10}Z$ = 51,5 dB(Ω), used in the above conversions is a constant originating from the calibration of field strength measuring equipment indicating the magnetic field in μV/m (or dB(μV/m)).

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15.3 Frequency range 150 kHz to 30 MHz

15.3.1 Electric antenna

Add, after the existing text, the following new text:

The unit of electric field strength shall be μV/m or, in logarithmic units, 20 log(μV/m) = dB (μVm). The associated emission limit shall be expressed in the same units.

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Add, after subclause 15.6, the following new subclause 15.7:

15.7 Special antenna arrangements

15.7.1 Loop antenna system

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

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

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

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

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

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

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Add, after subclause 16.6.3, the following new subclause 16.7:

16.7 Alternative test site suitability

There are many different test sites and facilities that have been constructed to make radiated emission measurements. Most are protected from the weather and the adverse effects of the radio frequency ambient. These include all weather-covered open area test sites and absorber-lined shielded rooms.

Whenever construction material encloses a test site, there is the possibility that the results of a single normalized site attenuation (NSA) measurement, as specified in 16.6, are not adequate to show such alternative site suitability.

To assess alternative test site suitability, the following procedure is recommended. It is based on making multiple NSA measurements throughout a volume occupied by the EUT. These NSA measurements shall all come within the error budget of ±4 dB to be judged suitable as an equivalent to an open area test site.

The discussion in this section concerns alternative test sites which have a conducting ground plane.

16.7.1 Normalized site attenuation for alternative test sites

For an alternative test site a single NSA measurement is insufficient to pick up possible reflections from the construction and/or RF-absorbing material comprising the walls and ceiling of the facility. For these sites a "test volume" is defined as that volume traced out by the largest equipment or system to be tested as it is rotated about its centre location through 360°, such as by a turntable. In evaluating horizontal and vertical polarization, such as illustrated in figures 51a and 51b, it may require a maximum of 20 separate site attenuation measurements, i.e. five positions in the horizontal plane (centre, left, right, front, and rear, measured with respect to the centre and a line drawn from the centre to the position of the measuring antenna), for two polarizations (horizontal and vertical), and for two heights (1 m and 2 m horizontal, 1 m and 1,5 m vertical).

These measurements are carried out with a broadband antenna and distances are measured with respect to the centre of the antenna. The transmit and receive antennas shall be aligned with the antenna elements parallel to each other and orthogonal to the measurement axis.

For vertical polarization, the off-centre positions of the transmit antenna are at the periphery of the test volume. Furthermore, the lower tip of the antenna shall be greater than 25 cm from the floor, which may require the centre of the antenna to be slightly higher than 1 m for the lowest height measurement.

For horizontal polarization measurements in the left and right positions if the distance between the construction and/or absorbing material on the side walls and EUT periphery is less than 1 m, the centre of the antenna is moved towards to central position so that the extreme tip of the antenna is either at the periphery or distant from the periphery by not more than 10 % of the test volume diameter. The front and rear positions are at the periphery of the test volume.

The number of required measurements can be reduced under the following circumstances:

a) The vertical and horizontal polarization measurements in the rear position may be omitted if the closest point of the construction and/or absorbing material is at a distance greater than 1 m from the rear boundary of the test volume.

NOTE – Radiated emission sources located near dielectric interfaces have been shown to have variations in current distribution that can affect the radiated properties of the source at that location. When EUT can be located near these interfaces, additional site attenuation measurements are required.

b) The total number of horizontal polarization measurements along the test volume diameter joining the left and right positions may be reduced to the minimum number necessary for the antenna footprints to cover 90 % of the diameter.

c) The vertical polarization measurements at the 1,5 m height may be omitted if the top of the EUT, including any table mounting, is less than 1,5 m in height.

d) If the test volume is no larger than 1 m in depth, by 1,5 m in width, by 1,5 m in height, including table if used, horizontal polarization measurements need only be made at the centre, front and rear positions but at the height of both 1 m and 2 m. If item a) above applies, the rear position may be omitted. This will require a minimum of eight measurements: four positions vertical polarization (left, centre, right, and front) for one height, and four positions horizontal polarization (centre and front) for two heights; see figures 51c and 51d.

NSA measurements shall be performed with the transmit and receive antenna separation held constant according to tables 16 and 17. Note that these tables have been modified to accommodate these NSA measurements by adding values for an additional transmit height and to limit the 30 m scan height to between 1 m and 4 m. The receive antenna must be moved to maintain the appropriate separation along a line towards the turntable centre (see figures 51a, 51b, 51c and 51d). The alternative test site is considered suitable for performing radiated emission testing if all NSA measurements prescribed above meet the requirements of 16.7.2 and the ground plane requirements of 16.7.3 below.

NOTE – Studies are underway to determine if any further tests are required to show alternate test site suitability.

16.7.2 Site attenuation

A measurement site shall be considered acceptable for radiated electromagnetic field measurements if the measured horizontal and vertical NSA measurements are within ±4 dB of the theoretical normalized site attenuation for an ideal site.

16.7.3 Conducting ground plane

A conducting ground plane is required at a radiated emission test site. The conducting ground plane shall extend at least 1 m beyond the periphery of the EUT and the largest measurement antenna, and cover the entire area between the EUT and the antenna. It shall be of metal with no holes or gaps having longitudinal dimensions larger than one-tenth of a wavelength at the highest frequency of measurement. A larger size conducting ground plane may be required if the NSA measurements do not meet the ±4 dB criterion.

NOTE – Ongoing studies may indicate the need for specifying minimum conductive ground plane size.

Table 16 – Normalized site attenuation (recommended geometries for tuned half-wave dipoles with horizontal polarization)

Polarization R h_1 h_2	Horizontal 3 m 2 m 1 m to 4 m	Horizontal 10 m 2 m 1 m to 4 m	Horizontal 30 m 2 m 1 m to 4 m
f_m MHz		A_N dB	
30	11,0	24,1	41,7
35	8,8	21,6	39,1
40	7,0	19,4	36,8
45	5,5	17,5	34,7
50	4,2	15,9	32,9
60	2,2	13,1	29,8
70	0,6	10,9	27,2
80	–0,7	9,2	24,9
90	–1,8	7,8	23,0
100	–2,8	6,7	21,2
120	–4,4	5,0	18,2
140	–5,8	3,5	15,8
160	–6,7	2,3	13,8
180	–7,2	1,2	12,0
200	–8,4	0,3	10,6
250	–10,6	–1,7	7,8
300	–12,3	–3,3	6,1
400	–14,9	–5,8	3,5
500	–16,7	–7,6	1,6
600	–18,3	–9,3	0
700	–19,7	–10,6	–1,4
800	–20,8	–11,8	–2,5
900	–21,8	–12,9	–3,5
1000	–22,7	–13,8	–4,5

Table 17 – Normalized site attenuation* (recommended geometries for broadband antennas)

Polarization R h_1 h_2	Horizontal 3 m 1 m 1 m to 4 m	Horizontal 10 m 1 m 1 m to 4 m	Horizontal 30 m 1 m 1 m to 4 m	Vertical 3 m 1 m 1 m to 4 m	Vertical 3 m 1,5 m 1 m to 4 m	Vertical 10 m 1 m 1 m to 4 m	Vertical 30 m 1 m 1 m to 4 m
f_m MHz	A_N dB						
30	15,8	29,8	47,8	8,2	9,3	16,7	26,0
35	13,4	27,1	45,1	6,9	8,0	15,4	24,7
40	11,3	24,9	42,8	5,8	7,0	14,2	23,5
45	9,4	22,9	40,8	4,9	6,1	13,2	22,5
50	7,8	21,1	38,9	4,0	5,4	12,3	21,6
60	5,0	18,0	35,8	2,6	4,1	10,7	20
70	2,8	15,5	33,1	1,5	3,2	9,4	18,7
80	0,9	13,3	30,8	0,6	2,6	8,3	17,5
90	–0,7	11,4	28,8	–0,1	2,1	7,3	16,5
100	–2,0	9,7	27	–0,7	1,9	6,4	15,6
120	–4,2	7,0	23,9	–1,5	1,3	4,9	14,0
140	–6,0	4,8	21,2	–1,8	–1,5	3,7	12,7
160	–7,4	3,1	19	–1,7	–3,7	2,6	11,5
180	–8,6	1,7	17	–1,3	–5,3	1,8	10,5
200	–9,6	0,6	15,3	–3,6	–6,7	1,0	9,6
250	–11,7	–1,6	11,6	–7,7	–9,1	–0,5	7,7
300	–12,8	–3,3	8,8	–10,5	–10,9	–1,5	6,2
400	–14,8	–5,9	4,6	–14,0	–12,6	–4,1	3,9
500	–17,3	–7,9	1,8	–16,4	–15,1	–6,7	2,1
600	–19,1	–9,5	0	–16,3	–16,9	–8,7	0,8
700	–20,6	–10,8	–1,3	–18,4	–18,4	–10,2	–0,3
800	–21,3	–12,0	–2,5	–20,0	–19,3	–11,5	–1,1
900	–22,5	–12,8	–3,5	–21,3	–20,4	–12,6	–1,7
1 000	–23,5	–13,8	–4,4	–22,4	–21,4	–13,6	–3,5

* This data applies to antennas that have at least 25 cm of ground plane clearance when the centre of the antennas is 1 m above the ground plane in vertical polarization.

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Replace existing clause 20 (under consideration) by the following new clause 20:

20 Coupling devices for measuring signal lines

The interference potential (and immunity) of signal lines may be assessed by measurement (or injection) of the conducted disturbance voltage or current. For this purpose coupling devices are needed to measure the disturbance component while rejecting the intentional signal on the line. The devices included are to measure the electromagnetic emission and immunity (common and differential mode, current and voltage). Typical devices for this kind of measurements are current probes and artificial networks (AN).

NOTE – Signal lines include telecommunication lines and terminals of equipment intended to be connected to these lines.

When the current probe is used and the limit value is specified in volts, the current value shall be multiplied by the impedance of the signal line or termination impedance as specified by the detailed measurement procedure. This impedance may be common mode or differential mode as required by the detailed measurement procedure.

Subclause 20.1 gives the specification for common mode (asymmetrical) artificial networks (T-Network). An example of an asymmetrical artificial network and its required parameters are given in annex S.

20.1 Requirements for asymmetrical artificial networks

Figure 52 shows the general circuit diagram for the artificial network.

The characteristics of the artificial network for the measurement of asymmetric disturbances shall be realized in the frequency band corresponding to the frequency band of the asymmetric disturbance voltages and the frequency band transmitted by the wanted signal. These characteristics are given in table 18.

Table 18 – Characteristics of the artificial network for the measurement of asymmetric disturbance

a)	**Termination impedance** of the network for the asymmetric disturbance voltage.		150 Ω ± 20 %
b)	**Differential mode rejection** of the network [1] Effective from input and output terminals, respectively, to the terminals of the measuring receiver.		> 70 dB [2]
c)	**Decoupling attenuation** for asymmetrical signals between the terminals for connection of the signal line (or associated equipment) and the EUT.		> 25 dB [2]
d)	**Insertion loss** of the symmetrical measuring circuit between terminals for connection of the EUT and the signal line (or associated equipment).		< 3 dB [2]
e)	**Symmetrical load impedance of the network** (To be realized by connection of a termination load, an associated signal simulator, or a signal line with a defined differential mode impedance, or by using a termination network)		t. b. d. [3]
f)	**Transmission bandwidth** for the wanted symmetrical signal (analogue or digital) .		t. b. d. [3]
g)	**Frequency range**	1) For emission	9 kHz to 30 MHz [4]
		2) For immunity	9 kHz to 150 MHz [4]

[1] The differential mode to common mode rejection is crucial to the usability of the asymmetrical network. The rejection of the network may be required to be greater than 70 dB when the intentional signal to interference limit ratio is greater than 70 dB at the frequency of the intentional signal.

[2] When the intentional signal frequency, including transmission bandwidth, is below the frequency range to be measured, requirements b, c, and d need not be observed.

[3] t. b. d. = to be defined (depending on intentional signal).

[4] More than one network may be used to cover the complete frequency range.

Add, after clause 20, the following new clause 21:

21 The artificial hand and series RC element

21.1 Introduction

In some product specifications the artificial hand is required for EUTs which do not have an earth ground connected to the metallic parts of the EUT and which in normal use are hand-held. Housings of plastic with a conductive coating may also require the use of the artificial hand. The artificial hand is used in conducted emission tests in the frequency range of 150 kHz to 30 MHz (the most critical frequencies are 5 MHz–30 MHz) to simulate the influence of the operator's hands on the measurements. The types of equipments to be evaluated with the artificial hand are: electric tools, household equipment, such as hand-held mixers, telephone handsets, joysticks, keyboards, etc.

21.2 Construction of the artificial hand and RC element

The artificial hand consists of a (strip of) metal foil of specified dimensions, which is placed on or wrapped around that part of the equipment normally touched by the user's hand, in a specified way.

The metal foil is connected in a specified way to the reference point of the disturbance measuring system via an RC element consisting of a capacitor C = 220 pF ± 20 % in series with a resistor R = 510 Ω ± 10 % (see figure 53a).

The strips of metal foil used to simulate the influence of a user's hand around an equipment handle or an equipment body are typically 60 mm wide. In the case of a keyboard a metal foil, or more practically a metal plate of maximum dimensions 100 mm × 300 mm, may be placed on top of the keys. Examples are given in figures 53 and 54.

The lead length between the RC element and the metal foil shall be 1 m long. If the test set-up requires a longer lead length, the total inductance of the lead shall be less than 1,4 µH if the frequency of measurement is near 30 MHz.

When considering the total of the interconnecting wires as a single wire in free space, the inductance L of the wire shall be less then 1,4 µH if the upper limit of the frequency range in the conducted emission test is 30 MHz. For a given single-wire length this requirement allows the calculation of the minimum diameter *d* (in m) of the wires to be used from

$$L = \frac{\mu l}{2\pi}\left[\ln\left(\frac{4l}{d}\right) - 1\right] \quad \text{(H)}$$

where

$\mu = 4\pi \times 10^{-7}$ H/m;

l is the length of the wire, in metres

d is the diameter of the wire, in metres

NOTE – When complying with the inductance requirement of 1.4 µH, the impedance of the RC network sufficiently dominates at 30 MHz.

21.2 The use of the artificial hand

The maximum length of wire between the RC element and the reference ground is generally met when the wire length does not exceed 1 m. The RC element may, for example, be placed either as close as possible to the metal foil or as close as possible to the reference point. The correct choice largely depends on the (generally unknown) internal common mode impedance of the disturbance source in the presence of the metal foil and the characteristic impedance of the transmission line formed by the connecting wire and its environment. If the frequency range of the emission measurements is limited to 30 MHz, the position of the RC element is not critical, and a practical position (also from the reproducibility point of view) of the RC element is inside the artificial mains network or the line impedance simulation network.

When the conducted emission to the mains is measured, the reference point is the reference ground in the artificial mains network (AMN). When this emission is measured on a signal or control line, the reference point is the reference ground of the line impedance simulation network (LISN). The general principle to be followed in the application of the artificial hand is that terminal M of the RC element shall be connected to any exposed non-rotating metalwork and to metal foil wrapped around all handles, both fixed and detachable, supplied with the appliance. Metalwork which is covered with paint or lacquer is considered an exposed metalwork and shall be directly connected to the RC element.

The following items specify the detailed application of the artificial hand:

a) When the housing of the appliance is entirely of metal and is earth-grounded, the artificial hand is not required.

b) When the case of the appliance is of insulating material, metal foil shall be wrapped around the handle B (figure 53c) and also around the second handle D, if present. Metal foil 60 mm wide shall also be wrapped around the body C (see figure 53c) at the point where the iron core of the motor stator is located, or around the gearbox if this gives a higher interference level. All these pieces of metal foil, and the metal ring or bushing A, if present, shall be connected together and to the terminal M of the RC element.

c) When the case of the appliance is partly metal and partly insulating material, and has insulating handles, metal foil shall be wrapped around the handles B and D (figure 53c). If the case is non-metallic at the location of the motor, a metal foil 60 mm wide shall be wrapped around the body C at the point where the iron core of the motor stator is located, or alternatively around the gearbox, if this is of insulating loading material and a higher interference level is obtained. The metal part of the body, the point A, the metal foil around the handles B and D and the metal foil on the body C shall be connected together and to the terminal M of the RC element.

d) When a class II appliance (without ground wire) has two handles of insulating material A and B and a case of metal C, for example an electric saw (figure 53c), metal foil shall be wrapped around the handles A and B. The metal foil at A and B and the metal body C shall be connected together and to terminal M of the RC element.

e) Figure 54 gives examples for a telephone handset and a keyboard. For the handset, the 60 mm wide foil is wrapped around the handle with some overlap of the foil. In the case of a keyboard the foil or the PCB should fully cover the keys as far as possible. Using a PCB, the metal side has to be placed on the keyboard. It does not, however, need to exceed the dimensions of 300 mm x 100 mm.

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Replace existing table G.4 by the following new table G.4:

Table G.4 – Mutual coupling correction factors for geometry using resonant tunable dipoles spaced 3 m apart

ΔAF_{TOT} – Total correction factor in decibels		
f_m MHz	Horizontal polarization R = 3 m h_1 = 2 m h_2 = 1 m to 4 m	Vertical polarization R = 3 m h_1 = 2,75 m h_2 = (see table G.3.)
30	3,1	2,9
35	4,0	2,6
40	4,1	2,1
45	3,3	1,6
50	2,8	1,5
60	1,0	2,0
70	–0,4	1,5
80	–1,0	0,9
90	–1,0	0,7
100	–1,2	0,1
120	–0,4	–0,2
125	–0,2	–0,2
140	–0,1	0,2
150	–0,9	0,4
160	–1,5	0,5
175	–1,8	–0,2
180	–1,0	–0,4

Notes

1) The values for the resonant dipoles were calculated using the method of moments and the numerical electromagnetic code (NEC) or the MININEC computer system.

G. J. Burke and A. J. Poggio, *Numerical Electromagnetic Code – Method of Moments,* Lawrence Livermore Laboratory, California, January, 1981.

J. W. Rockway, J. C. Logan, D. W. S. Tam, S. T. Li, *The MININEC System: Microcomputer Analysis of Wire Antennas*, Artech House, Boston, 1988.

Berry, J.; Pate, B.; Knight: "Variations in Mutual Coupling Correction Factors for Resonant Dipoles Used In Site Attenuation Measurements", Proc IEEE Sym on EMC, Washington, DC, 1990.

2) Theoretical free-space antenna factors for ideal resonant dipoles with a 0,5 dB balun loss (for each antenna) are assumed.

3) These correction factors do not completely describe antenna factors measured above a ground plane, e.g. at heights of 3 or 4 m, since these antenna factors differ from free-space antenna factors at the lower frequencies. However, within the error bounds described in table M, the values are adequate to indicate site anomalies.

4) The user is cautioned that some half-wavelength dipoles or antennas with unusual baluns may exhibit different characteristics than the antenna in G.5.

5) Mutual coupling correction factors for 10 m and 30 m are under consideration. As an interim procedure, site adequacy can be assessed by considering these correction factors to be equal to zero.

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Add, after annex P, the following new annex Q:

Annex Q
(normative)

Parameters of broadband antennas

Q.1 Introduction

As new and improved antennas are used in making both radiated emission and immunity measurements over wide frequency ranges using scanning receivers or spectrum analysers, it is very helpful to provide specific parameters that can be used in comparing the attributes and usefulness of such broadband antennas. Various CISPR publications specify particular antennas to be used in making measurements. Tuned half-wave resonant dipoles are most notably mentioned above 80 MHz. Generally, other types of antennas, normally broadband in nature, can be used provided the results are equivalent to those obtained with the specified antenna. The comparison of these broadband antennas to the specified antennas or to other broadband antennas will be aided by listing appropriate parameters. These parameters shall be specified as part of any CISPR contribution recommending new antenna usage. Antenna manufacturers shall also use this information as guidance in specifying the most useful aspects of broadband antennas used in making interference measurements. It is not the intent of CISPR, however, to show a preference for any particular broadband antenna over that for tuned dipoles.

Q.2 Broadband antenna parameters

Broadband antennas used for CISPR measurements are those antennas that are linearly polarized and are intended for use over a wide frequency range. This does not prevent the use of antennas with limited length adjustment nor the addition of antenna element sections. The impedance of such antennas are typically comprised of both real and imaginary impedances. Other parameters that can be specified are contained below.

Q.2.1 Antenna type

The following parameters describe the physical parameters of broadband antennas that should be provided. Note that some parameters may not apply to each antenna.

Q.2.1.1 Antenna style of fixed or variable length or diameter

If the antenna has a variable length, specify the number of sections that are added or subtracted to change the basic fixed length.

NOTE – Fully tunable antennas are not considered to be broadband and hence would not be specified herein. The diameter of loop antennas are generally not variable.

Q.2.1.2 Depth to width ratio or loop diameter

Provide dimension in metres. For a log periodic array, for example, the length of the boom along the measurement axis and the width of the largest element would be provided.

Q.2.1.3 Active or passive antenna

A broadband antenna is considered an active antenna if it contains amplifiers, preamplifiers, and other non-linear active devices which amplify the signal and or shape the frequency response.

Q.2.1.4 Mounting arrangement

Provide any special mounting requirements beyond those which can be accommodated by a typical tripod or antenna positioner.

Q.2.1.5 Connector type

Specify BNC, N, SMA, etc. as appropriate.

Q.2.1.6 Balun type

Specify if balun is discrete, distributed, tunable, etc.

Q.2.2 Specification of the antenna

Q.2.2.1 Frequency range

Specify the frequency range in megahertz or kilohertz where the antenna operates within its characteristics. If there is a defined fall-off characteristic in decibels per octave at either end of the range, so specify.

Q.2.2.2 Gain and antenna factor

Q.2.2.2.1 Gain

Specify typical or actual gain in decibels relative to an isotropic radiator (dBi).

Q.2.2.2.2 Antenna factor

Specify typical or actual antenna factor in decibels per metre.

Both gain and antenna factor should be measured using the calibration procedure in Q.2.3.1.

Q.2.2.3 Directivity and pattern for linearity polarization

Specify antenna pattern and directivity in degrees with a polar plot in both the E and H planes. For less directional antennas, specify the front-to-back ratio in decibels. If omnidirectional, so state.

Q.2.2.4 VSWR and impedance

Indicate the maximum VSWR and nominal input impedance in ohms.

Q.2.2.5 Active antenna performance

For antennas with active amplified gain, specify the intermodulation product levels, its electric and magnetic field strength immunity level from outside disturbances, and any appropriate check to determine overload or improper operation.

Q.2.2.6 Power handling

For immunity use specified maximum and transient power handling capability in watts.

Q.2.2.7 Other conditions

Specify the temperature and humidity range in which the antenna must operate and any precautions if used in an unprotected area exposed to the weather.

Q.2.3 Antenna calibration

Q.2.3.1 Method of calibration for emission measurements

Identify the method used for calibration, i.e.:

a) calculated (indicate formula used);

b) measured (specify the method or standard used or the traceability to national calibration laboratory, and whether antennas are calibrated individually).

NOTE – For immunity measurements, field strength calibrations are generally made using a secondary calibrated antenna located at the place of the appliance being subjected to the radiation. Hence, no calibrations are required on the transmit antenna.

Q.2.3.2 Frequency interval

Indicate the frequencies in megahertz or kilohertz used during the calibration process; if a swept frequency procedure is used, so state.

Q.2.3.3 Accuracy of calibration

Specify the nominal accuracy of the calibration in ± decibels. Indicate the worst case accuracy and the portion of the frequency band where that occurs.

Q.2.3.4 Correlation with preferred or specified antennas

If the antenna is to be substituted for a preferred or specified antenna cited in a CISPR publication, indicate all correlation factors in decibels to equate the broadband antenna results to those of the preferred or specified antenna. Also indicate any conversion factor used to convert from the magnetic field intensity or vice versa or for any other conversion to a measurement unit other than a field strength quantity.

Q.2.3.5 Units

Specify calibration in units that are necessary to make magnetic or electric field strength emission measurements.

Q.2.4 Antenna user information

Q.2.4.1 Antenna use

Provide a description of the use of the antenna. Ensure that any special precautions or limitations are cited to reduce the chance of misuse.

Q.2.4.2 Physical limitations

Indicate if there are any physical limitations in using the antenna such as the following:

a) minimum height above the ground plane;

b) preferred polarization with respect to the ground plane;

c) special use, i.e. use as a receive antenna or a transmit antenna only. Normally, this is limited to the power handling capability of the balun for passive antennas or the non-bidirectional characteristics for active antennas;

d) simple ohmic check to determine continuity integrity of antenna;

e) minimum separation of the closest antenna element to the appliance being measured.

Add, after annex Q, the following new annex R:

Annex R
(normative)

Loop antenna system for magnetic field induced current measurements in the frequency range of 9 kHz to 30 MHz

R.1 Introduction

This annex sets forth information and data concerning the loop antenna system (LAS) to measure the current induced in the LAS by the magnetic field emitted by a single EUT, positioned in the centre of the LAS, in the frequency range of 9 kHz to 30 MHz. Subclauses 15.7 of CISPR 16-1 and 2.6.5 of CISPR 16-2 refer to this LAS.

A description of the LAS is given, as well as the method of validation of the antennas of the LAS. Conversion factors are given to relate magnetic field induced current data to magnetic field data which would have been obtained when the same EUT was measured using a single-loop magnetic field antenna positioned at a specified distance from that EUT. The latter measuring method is given in section 2 of CISPR 16-1.

R.2 Construction of the loop antenna system (LAS)

The LAS, figure R.1, consists of three mutually perpendicular large-loop antennas (LLAs), described in clause R.3. The entire LAS is supported by a non-metallic base.

A 50 Ω coaxial cable between the current probe of an LLA and the coaxial switch, and between this switch and the measuring equipment, shall have a surface transfer impedance smaller than 10 mΩ/m at 100 kHz and 1 mΩ/m at 10 MHz. This requirement is met when using, for example, double-braided shield RG 223/U coaxial cable.

All connectors shall have a surface transfer impedance comparable with that of the coaxial cable. This requirement is met, for example, when using good quality BNC collet-lock type connectors (see IEC 60169-8*).

All cables shall be equipped with ferrite absorbers, F in figure R.1, providing a common-mode series resistance of R_S > 100 Ω at 10 MHz. This requirement is met when constructing the ferrite toroid from, for example, 12 rings of type 3E1 from Ferroxcube (minimum size in millimetres: 29 O.D. x 19 I.D. x 7,5 Ht).

R.3 Construction of a large-loop antenna (LLA)

A large-loop antenna (LLA) of the LAS is constructed from coaxial cable of which the surface transfer impedance has been specified in clause R.2. In addition, the resistance of the inner conductor of the LLA shall be sufficiently low (see note 1). Both requirements are met, for example, when using double-braided shield RG 223/U coaxial cable.

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* IEC 60169-8: 1978, *Radio-frequency connectors – Part 8: RF coaxial connectors with inner diameter of outer conductor 6,5 mm (0,256 in) with bayonet lock – Characteristic impedance 50 ohms (Type BNC).*

To keep the loop in its circular shape and to protect the slit construction, as in the example of figure R.2, the cable is inserted in a thin walled non-metallic tube with inner diameter of approximately 25 mm. Other non-metallic constructions serving the same purposes may be used.

The loop diameter has been standardized to be D = 2 m. If necessary, e.g. the case of large EUT, D may be increased. However, in the frequency range up to 30 MHz the maximum allowable diameter is 4 m. Further increase of the diameter would result in non-reproducible resonances of the LAS response at the high-frequency end of the measuring range.

It should be noted that by increasing the diameter, its sensitivity to ambient noise increases proportionally to the diameter, and its sensitivity to wanted signals is inversely proportional with the diameter squared.

An LLA contains two opposite slits, positioned symmetrically with respect to the current probe of the LLA (see figure R.2). Such a slit, made in the outer conductor of the coaxial antenna cable as shown in figure R.3, shall have a width of less than 7 mm. The slit is bridged by two parallel sets of 100 Ω resistors in series. The centre of each series circuit is connected to the inner conductor of the coaxial antenna cable.

At each side of the slit the outer conductor of the coaxial antenna cable may be bonded to a strap of printed circuit board material with two copper rectangles, separated by at least 5 mm, in order to obtain a rigid slit construction (see figure R.4).

The current probe around the inner conductor of the coaxial antenna-cable shall have a sensitivity of 1 V/A over the frequency range of 9 kHz to 30 MHz. The insertion loss of the current probe shall be sufficiently low (see note 1).

The outer conductor of that cable shall be bonded to the metal box containing the current probe (see figure R.5). The maximum dimensions of this box are the following: width 80 mm, length 120 mm and height 80 mm.

NOTE 1 – To obtain a flat frequency response of the LLA at the lower end of the frequency range of 9 kHz to 30 MHz, the insertion loss R_c, of the current probe should be much smaller than $2 \pi f L_c$ at f = 9 kHz, where L_c represents the inductance of the current probe. In addition, $(R_c + R_i) \ll X_i = 2 \pi f L$ at 9 kHz, where R_i is the resistance of the inner conductor of the loop and L is the loop inductance. This inductance is about 1,5 μH/m of circumference, Hence for the standardized LLA, $X_i \approx 0,5\ \Omega$ at f = 9 kHz.

NOTE 2 – To avoid unwanted capacitive coupling between the EUT and the LAS, the distance between the EUT and components of the LLA shall be at least 0,10 times the loop diameter. Particular attention must be paid to the leads of an EUT. Cables should be routed together and leave the loop volume in the same octant of the cell, no closer than 0,4 m to any of the LAS loops (see figure R.6).

R.4 Validation of a large-loop antenna (LLA)

The validation and calibration of a large-loop antenna (LLA) of the loop antenna system is carried out by measuring the current induced in the LLA by the balun-dipole connected to a 50 Ω RF generator, described in clause R.5. The magnetic field emitted by that dipole allows verification of the magnetic field sensitivity of the LLA. The electric field emitted by the balun-dipole shows that the electric field sensitivity of the LLA is sufficiently low.

The induced current shall be measured as a function of frequency in the range of 9 kHz to 30 MHz at the 8 positions of the balun-dipole in figure R.7. During this measurement the balun dipole is in the plane of the LLA under test.

In each of the eight positions, the ratio [expressed in dB(Ω) = 20 log (R1/R2)] of the open circuit voltage of the RF generator and the measured current shall not deviate more than ±2 dB from the validation factor given in figure R.8.

The validation factor given in figure R.8 is valid for a circular LLA with a standardized diameter D = 2 m. If the diameter of a circular LLA differs from D = 2 m, the validation factor for the non-standardized LLA can be derived from the data given in figures R.8 and R.11 (clause R.6).

R.5 Construction of the balun-dipole

The balun-dipole, figure R.9, has been designed to emit simultaneously a magnetic field, which should be measured by the LLA, and an electric field, which should be rejected by the LLA.

The balun-dipole is constructed from RG 223/U coaxial cable. It has a width W = 150 cm and a height H = 10 cm (cable centre to cable centre distances), as depicted in figure R. 9.

A slit in the outer conductor of the coaxial cable divides the dipole in two halves. One half of this dipole, the right-hand half in figure R.9, is short-circuited near the slit as well as near the connector. Short-circuited means that the inner and outer conductors of the coaxial cable are electrically bonded together. This half is connected to the reference-ground of the BNC connector. The inner conductor of the coaxial cable, forming the left-hand half of the dipole in figure R.9, is connected to the centre-pin of the BNC connector and its outer conductor to the reference ground of that BNC connector.

A small metal box is used to screen the connections near the dipole connector. The outer conductor of the two halves of the coaxial dipole cable are bonded to this box, as is the reference ground of the BNC connector.

To obtain a rigid construction the dipole is supported by a non-conductive base.

R.6 Conversion factors

This clause deals with the factor which converts the current (I) induced in the LLA by the EUT into a magnetic field strength H at a specified distance from the EUT (see figure R.10). It also deals with the factor which converts the current measured in an LLA with a non-standardized diameter to a current which would have been measured using an LLA with the standardized diameter of D = 2 m (see figure R.11).

The conversion factor in figure R.10 applies to a source of magnetic field positioned in the centre of the LLA with its dipole moment perpendicular to the plane of that LLA. It should be noted that with the loop antennas specified in 15.2, the loop antenna is always positioned in a vertical plane and the EUT is only rotated around its vertical axis. Hence, in that case only the horizontal dipole moments, i.e. the dipole moments parallel to the ground plane, are measured. Consequently, in the case of a vertical dipole moment the conversion factor cannot be used to compare results of both measuring methods. However, the factor can be used when in the magnetic field measuring method the loop antenna would be positioned in a horizontal plane, or when in that method the EUT would be tilted through 90°, so that the relevant vertical dipole moment is changed into a horizontal one.

If the actual position of a disturbance source inside an EUT is at a distance less than 0,5 m from the centre of the standardized LAS, the measuring results differ by less than 3 dB from those with that source in the centre.

The relation between the magnetic field strength H in dB(μA/m) measured at a distance d and the current I in dB(μA) is:

$$H\,[\mathrm{dB}(\mu A/m)] = I\,[\mathrm{dB}(\mu A)] + C_{dA}\ (\mathrm{dBm}^{-1})$$

where C_{dA} is the current-to-field conversion factor for a certain distance d when expressing H in dB(μA/m) see also the note after the following equation.

In general, the conversion factor is frequency-dependent; figure R.10 presents C_{dA} for standardized distances of 3 m and 10 m. For the standardized distance d = 30 m the conversion factor is under consideration.

The ratio S_D in decibels, of the current measured in a LLA with a diameter D, in metres, and the current which would have been measured with an LLA having the standardized diameter D = 2 m, are given in figure R.11 for several values of D. Using this ratio, the equation given above can be written as:

$$H\,[\mathrm{dB}(\mu A/m)] = I\,[\mathrm{dB}(\mu A)] - S_D(\mathrm{dB}) + C_{dA}\ (\mathrm{dBm}^{-1})$$

NOTE – For disturbance calculations, CISPR uses the magnetic field strength H in dB(μA/m) instead of dB(μV/m). In this context, the relation between H expressed in dB(μA/m) and H expressed in dB(μV/m) is given by:

$$H\,[\mathrm{dB}(\mu V/m)] = H\,[\mathrm{dB}(\mu A/m)] + 51{,}5\ [\mathrm{dB}(\Omega)]$$

For convenience the conversion factor C_{dV} converting I [dB(μA)] into H [dB(μV/m)] is also given in figure R.10.

The following examples explain the use of the three equations above and of figures R.10 and R.11.

a) Given: measuring frequency F = 100 kHz, loop diameter D = 2 m, current in loop I = X dB(μA)

   Then using the first equation and figure R.10, it follows that:

   at d = 3 m: $H\,[\mathrm{dB}(\mu A/m)] = X\,[\mathrm{dB}(\mu A)] + C_{3A}\ (\mathrm{dBm}^{-1}) = (X - 19{,}5)\ \mathrm{dB}(\mu A/m)$

   at d = 3 m: $H\,[\mathrm{dB}(\mu V/m)] = X\,[\mathrm{dB}(\mu A)] + C_{3V}\ [\mathrm{dB}(\Omega/m)] = [X + (51{,}5 - 19{,}5)]\ \mathrm{dB}(\mu V/m)$

b) Given: measuring frequency f = 100 kHz, loop diameter d = 4 m, current in loop I = X dB(μA)

   Then using figure R.11 it follows that the same EUT would have induced a current:

   $I\,[\mathrm{dB}(\mu A)] = X - S_3\ (\mathrm{dB}) = (X + 13)\ \mathrm{dB}(\mu A)$

   in the LLA with the standard diameter D = 2 m.

c) Given: validate an LLA with diameter D = 3 m:

   Then the validation factor is found by adding at each frequency S_3, as given in figure R.11, to the validation factor, as given in figure R.8. Hence, if the measuring frequency is 100 kHz, the validation factor for the LLA with D = 3 m equals (86 – 7) = 79 dB(Ω)

R.7 Reference document

A Large-Loop Antenna for Magnetic Field Measurements, J. R Bergervoet and H. Van Veen, Proceedings of the 8th International Zürich Symposium on EMC, pp 29-34, March 1989, ETH Zentrum - IKT, 8092 Zürich, Switzerland.

Add, after annex R, the following new annex S:

Annex S
(normative)

Example of an asymmetrical artificial network (T-network)

S.1 Description

Figure S.1 gives as an example of an artificial asymmetrical network, a T-network having terminals a_1 and b_1 for connection to a conductor pair in a signal port of an EUT and RG for connection to the reference ground plane and, if applicable, to the safety earth or other ground connector of the EUT.

The symmetrical signal which may be needed to have the EUT operating correctly is connected to the terminals a_2 and b_2. The double choke L_1 allows separate measurement of the asymmetric component of the disturbance. The two windings are so arranged that the symmetrical currents are blocked by a high impedance whereas the impedance (for asymmetrical currents passing to R_E) shall be negligible.

The termination impedance of the network for the asymmetric disturbance voltage of 150 Ω is determined by the two resistors R_T (200 Ω), in parallel for the asymmetrical current, in series with the resistance R_E (50 Ω). The resistor R_E is usually the input impedance of a measuring receiver. In this case the meter reading is 10 dB lower than the actual asymmetrical value at the terminal of the EUT. The capacitor C_T is blocking d.c. currents thus allowing for d.c. supply voltages on the network leads without damaging the resistors and without influencing the properties of L_1 by saturation.

Normally a T-network is inserted between an EUT and its associated equipment.

When using the network for measurement on signal terminals, the symmetric (differential mode) rejection must be sufficient to avoid erroneous results when measuring an asymmetric interference voltage at the same frequency as the wanted symmetric signal. For a linear and passive network like a T-network, the common mode rejection is equal to the differential mode rejection. This principle is used to verify the common mode rejection.

S.2 Measurement of parameters

To fulfill the requirements of 20.1, the procedure for the measurement of parameters described below is used.

a) **Termination impedance**

This impedance between the terminals a_1 and b_1 connected together, and terminal RG shall be checked with terminals a_2 and b_2 being alternatively open and short-circuited to the earth terminal RG, with the termination network removed (see figure S.2).

b) **Differential mode rejection**

This rejection shall be measured as per figure S.3. The RF generator G, having an internal impedance of 50 Ω and a source voltage U_L, applies a signal between the centre-tap of the primary windings of the transformer L_1 and the reference ground. As a result, a common mode signal is applied to the terminals a_1 b_1 of the T-network, while its terminals a_2 b_2 are terminated by the prescribed impedance $Z_2 = 150\ \Omega$.

The voltmeter, having an input impedance of 50 Ω, measures via the transformer the differential mode signal in the loop containing the T-network and Z_2. A differential mode signal may result in this loop from the common mode/differential mode conversion (the unbalance) of the T-network.

The common mode rejection (c.m.r.) and consequently the differential mode rejection (d.m.r.) is now defined as

$$\text{c.m.r.} = \text{d.m.r.} = 20 \log_{10} [U_L/U_T] \quad \text{(dB)}$$

The quality (i.e., the balance) of the transformer shown in figure S.2 is verified by grounding the primary of the transformer at terminals a_1 and b_1 (the T-network is disconnected). The output voltage U_T shall be at least 10 dB lower than the differential mode rejection specified in 20.1 (i.e. the rejection shall be 70 + 10 = 80 dB) with reference to the input signal (U_L). The output signal (U_T) shall be $U_T = U_L - 70\ \text{dB} - 10\ \text{dB}$.

c) **Decoupling attenuation**

The decoupling shall be measured as per figure S.3.

d) **Insertion loss**

The insertion loss shall be measured as per figure S.4.

e) **Symmetrical load impedance**

To be defined.

f) **Transmission bandwidth**

To be defined.

S.3 Available T-networks

The presently available T-networks are usable for the measurement of two-wire telephone wires and modem signals of up to 10 kilobits/second. The limitation is the differential mode rejection which is as follows:

95 dB at 10 kHz

70 dB at 1 MHz

60 dB at 10 MHz

50 dB at 30 MHz

These networks provide an asymmetric load impedance of approximately 150 Ω.

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Add, after figure 50, the following new figures:

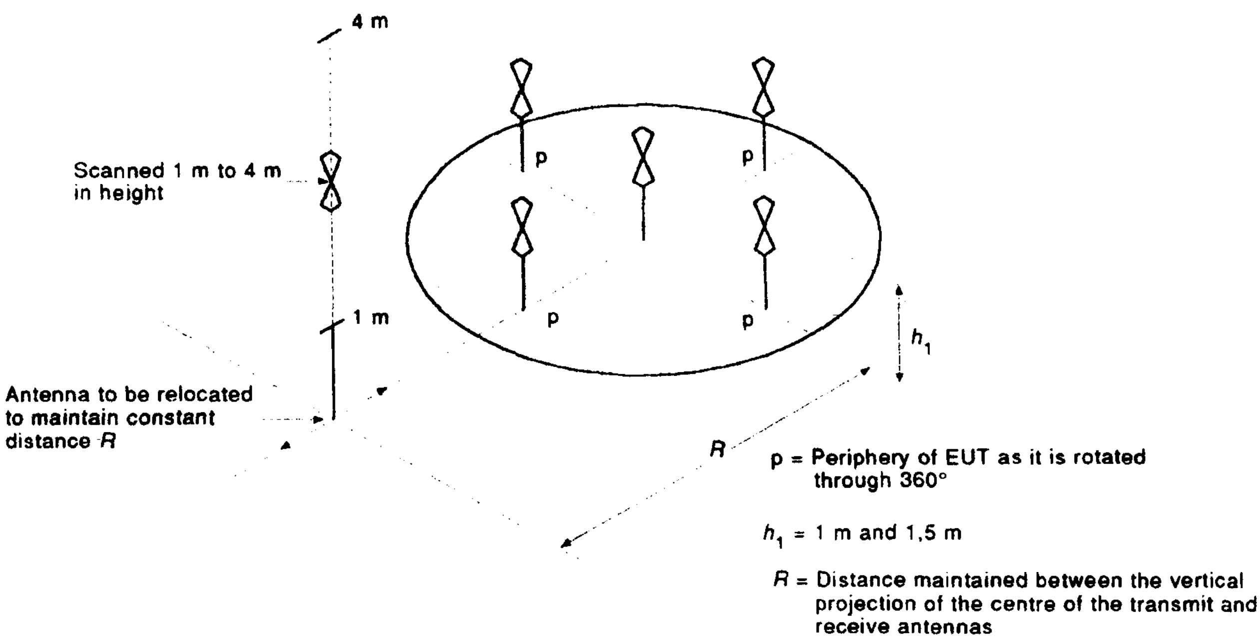


Figure 51a – Typical antenna positions for alternative test site – Vertical polarization NSA measurements

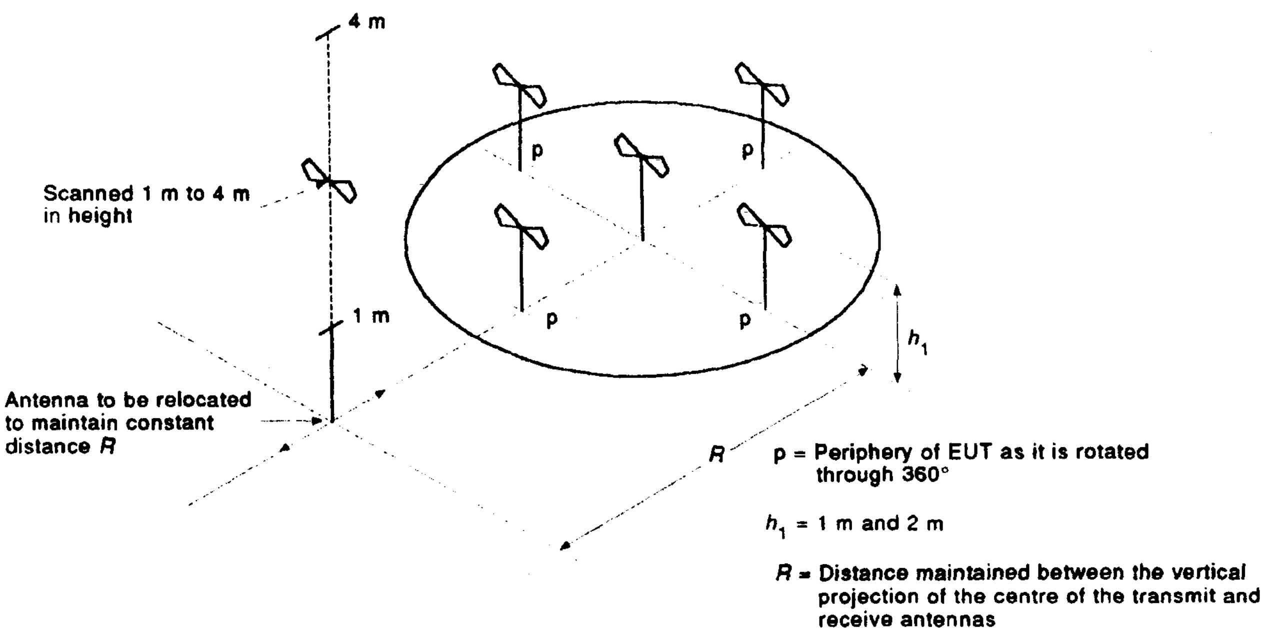


Figure 51b – Typical antenna positions for alternative test site – Horizontal polarization NSA measurements

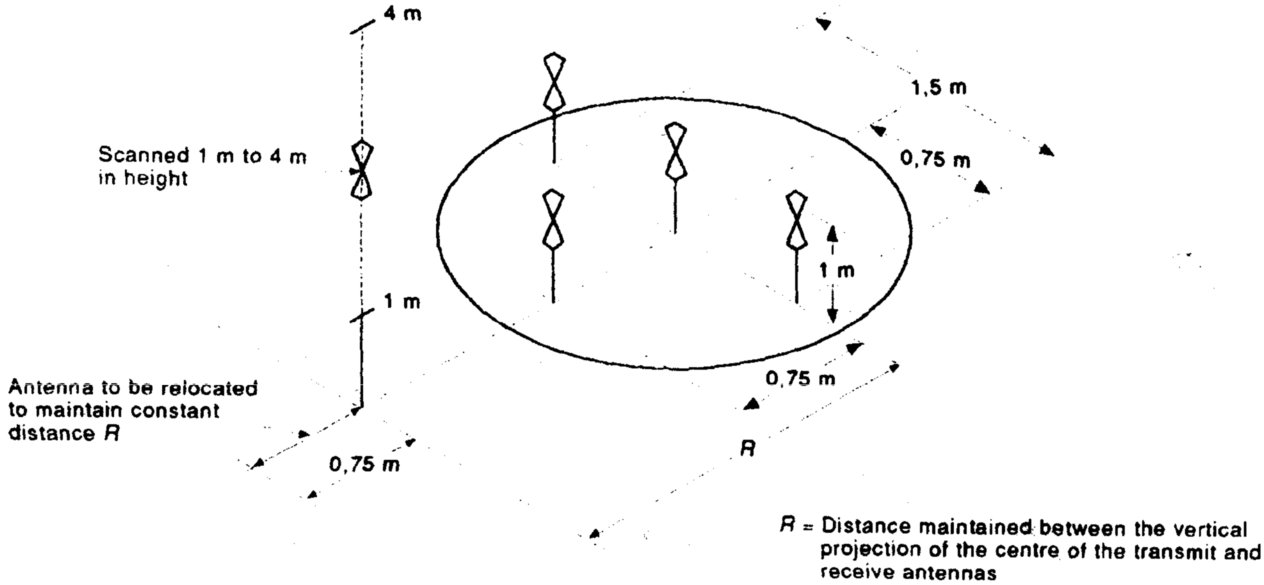


Figure 51c – Typical antenna positions for alternative test site – Vertical polarization NSA measurements for an EUT that does not exceed a volume of 1 m depth, 1,5 m width, 1,5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections

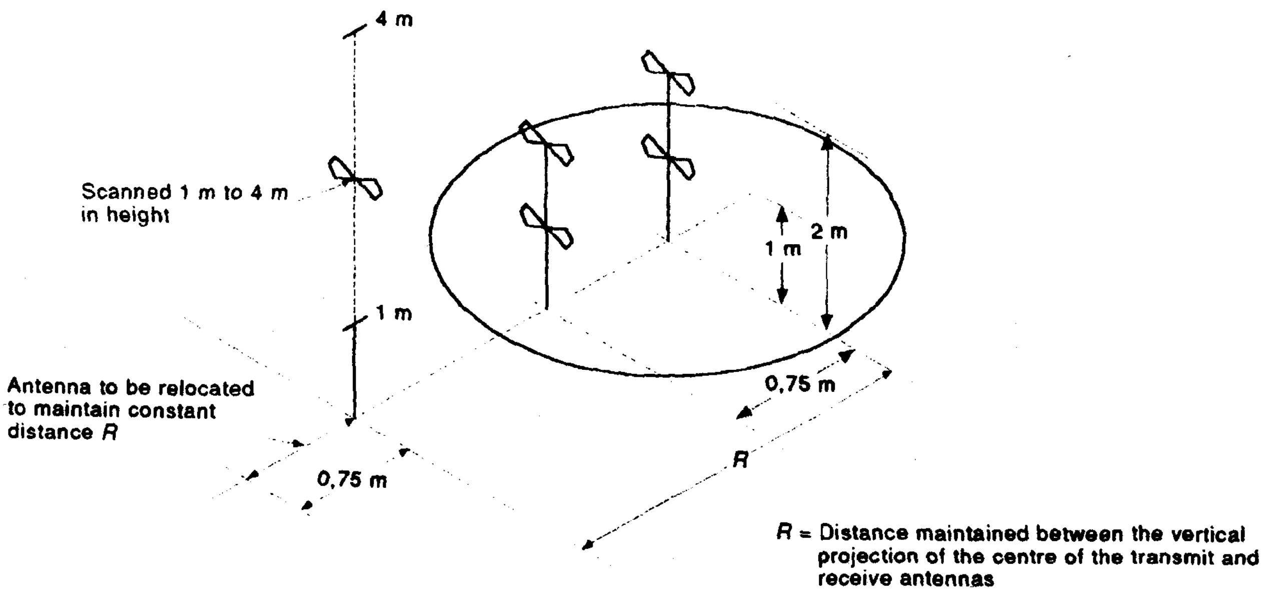


Figure 51d – Typical antenna positions for alternative test site – Horizontal polarization NSA measurements for an EUT that does not exceed a volume of 1 m depth, 1,5 m width and 1,5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections

Figure 51 – Typical antenna positions for alternative test sites

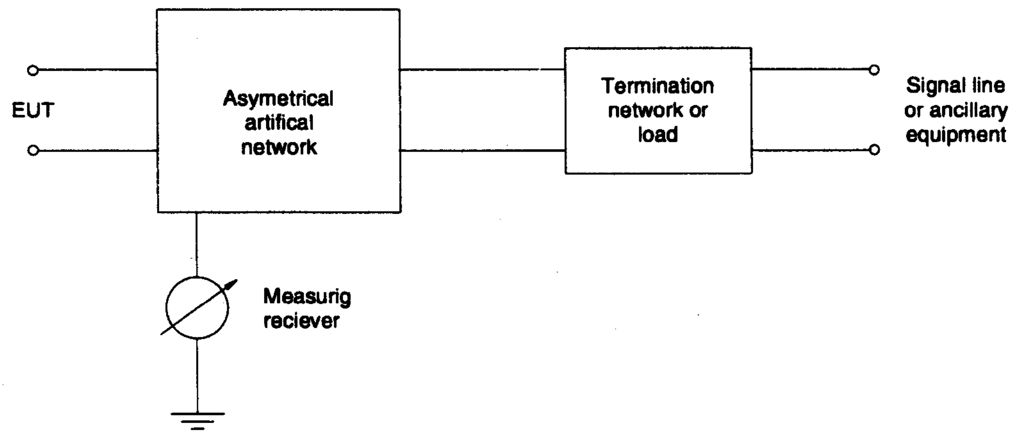


Figure 52 – Principle circuit of asymmetrical artificial network and its connections

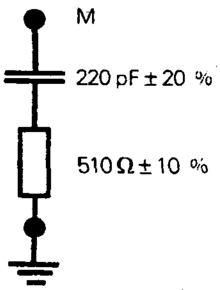


Figure 53a – RC element

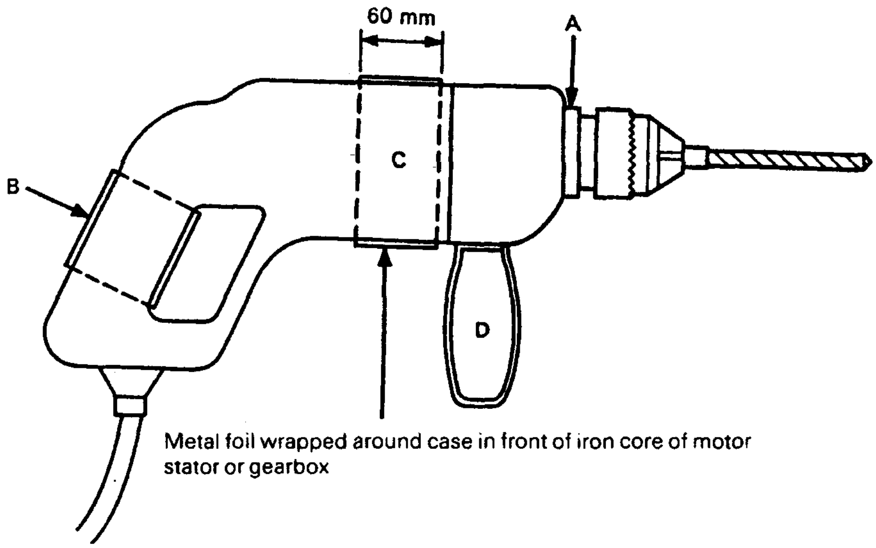


Figure 53b – Portable electric drill

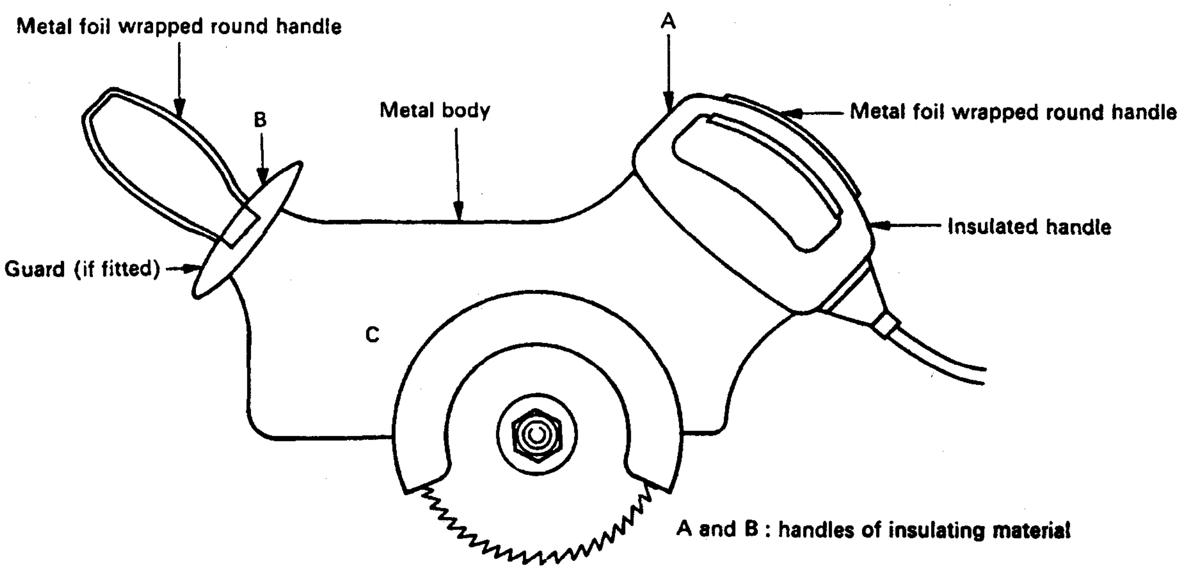


Figure 53c – Portable electric saw

Figure 53 – Application of the artificial hand

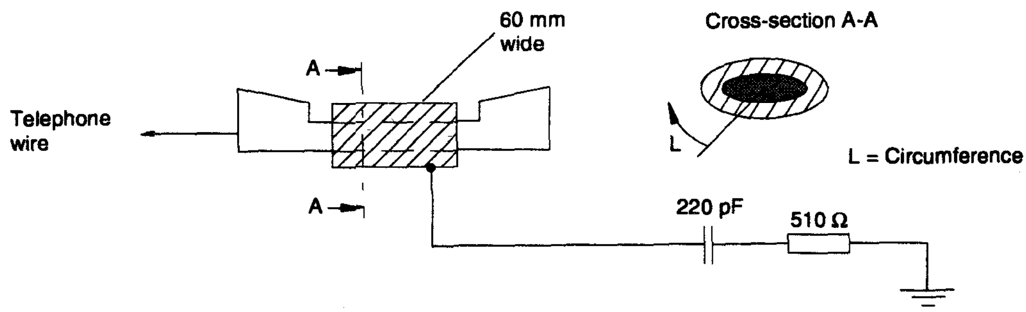


Figure 54a – Application of artificial hand to telephone handset

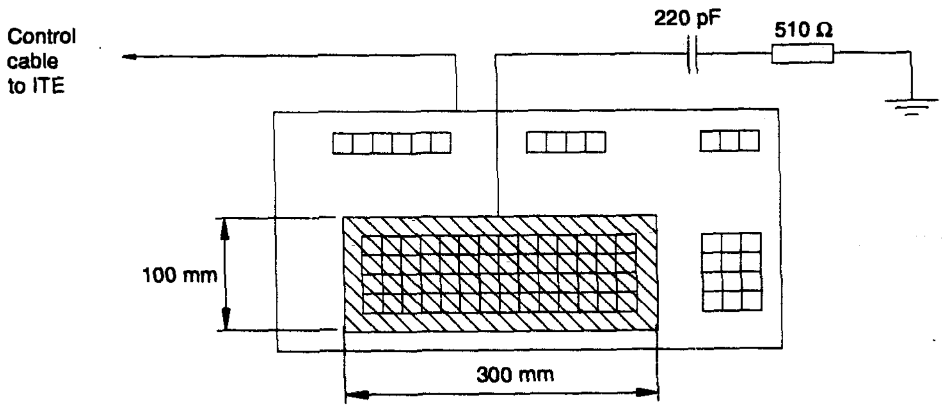
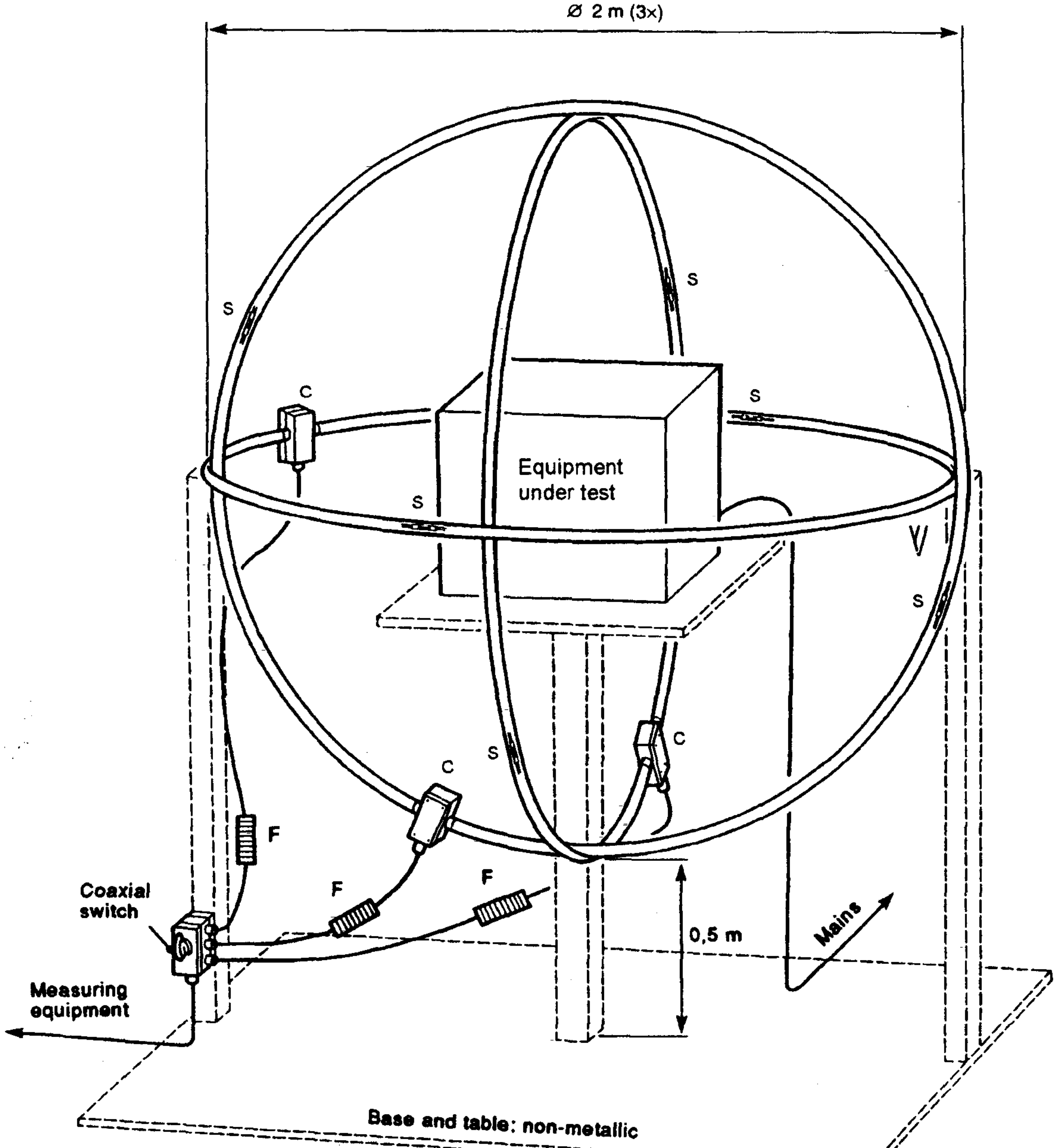


Figure 54b – Application of artificial hand to typical keyboard

The artificial hand incorporates a metal foil, with the following dimensions:

a) 60 mm wide and greater than L in length	for parts of the equipment that are hand-held during operation, or at a maximum of 4
b) 300 mm × 100 mm	for keyboards, whereby the metal foil is to be sized in order to cover the total number of keys, or to partially cover the keyboard, when the keyboard dimensions are greater than the maximum foil size.

Figure 54 – Examples of application of artificial hand to ITE



S = antenna slit

C = current probe

F = ferrite absorber

Figure R.1 – The loop-antenna system, consisting of three mutually perpendicular large-loop antennas

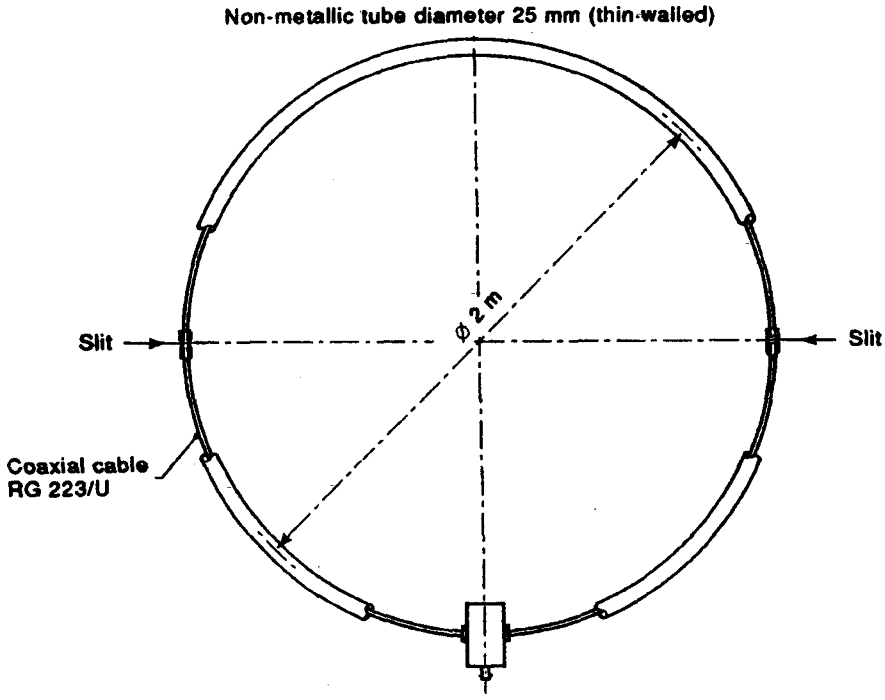


Figure R.2 – A large-loop antenna containing two opposite slits, positioned symmetrically with respect to the current probe C

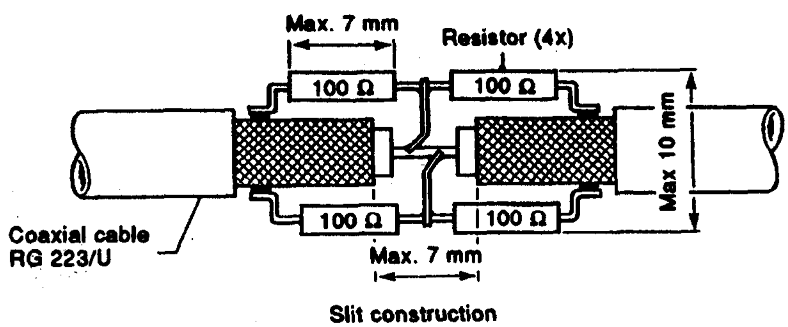


Figure R.3 – Construction of the antenna slit

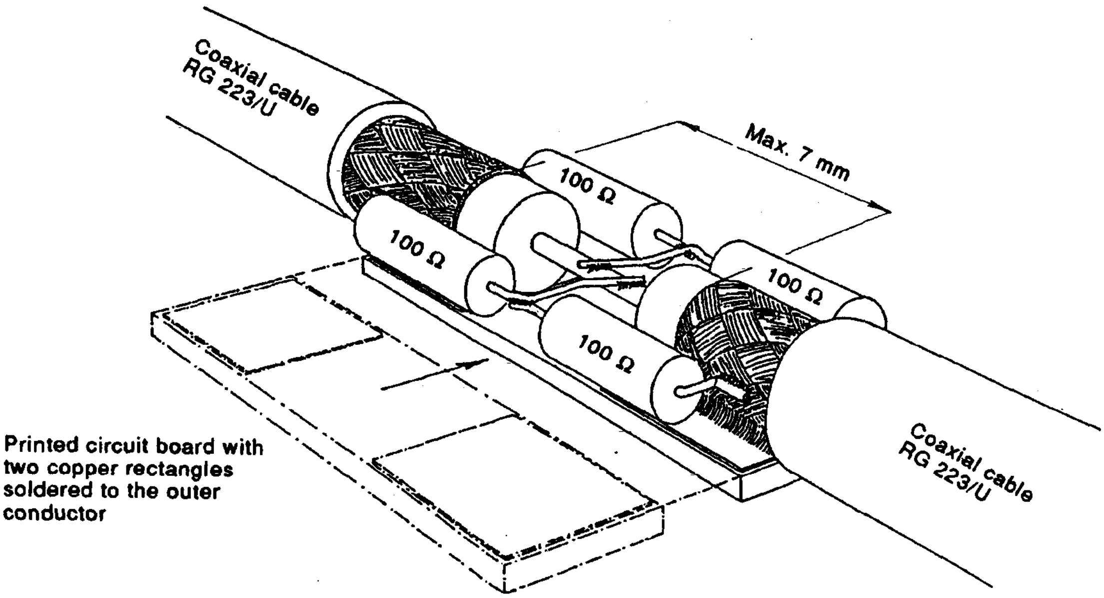


Figure R.4 – Example of antenna-slit construction using a strap of printed circuit board to obtain a rigid construction

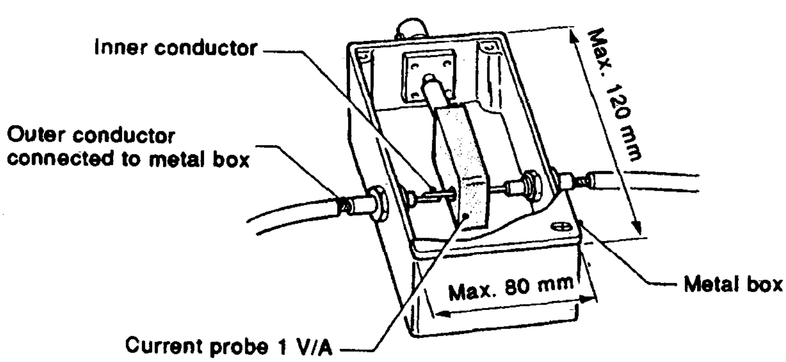


Figure R.5 – Construction for the metal box containing the current probe

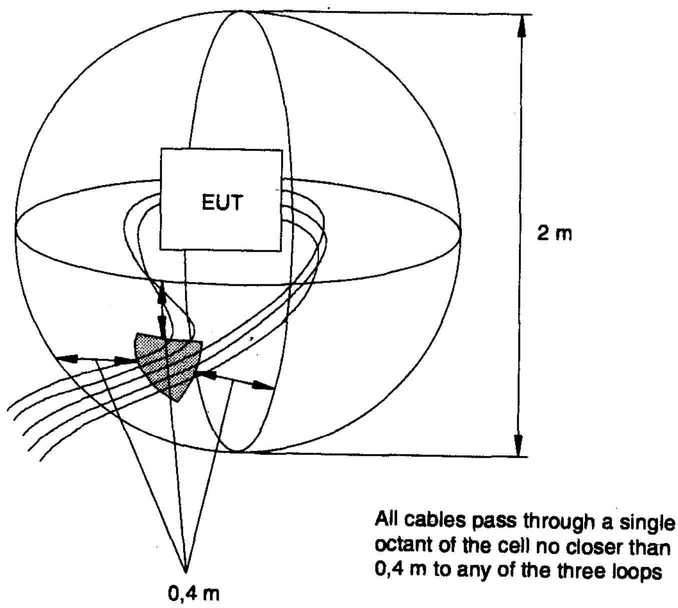


Figure R.6 – Example showing the routing of several cables from an EUT to ensure that there is no capacitive coupling from the leads to the loop

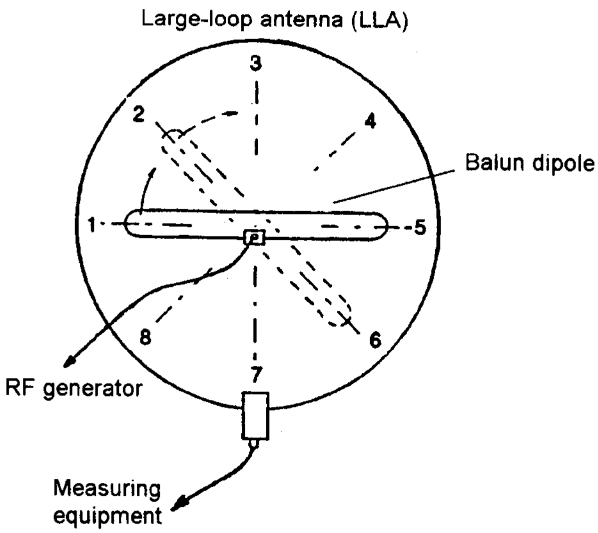


Figure R.7 – The eight positions of the balun-dipole during validation of the large-loop antenna

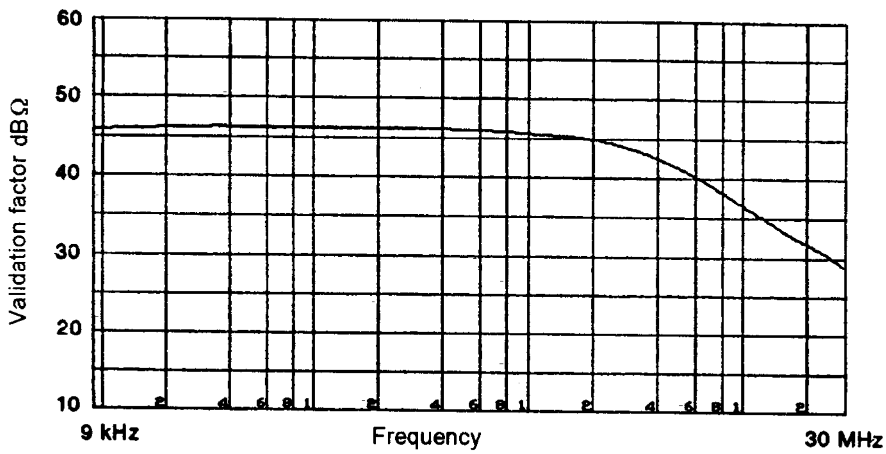


Figure R.8 – The validation factor for a large loop-antenna of 2 m diameter

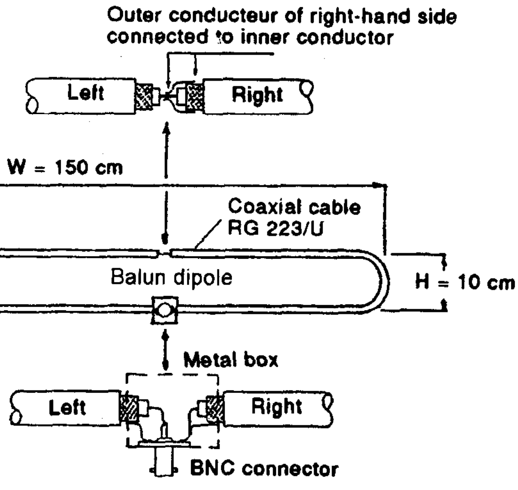


Figure R.9 – Construction of the balun-dipole

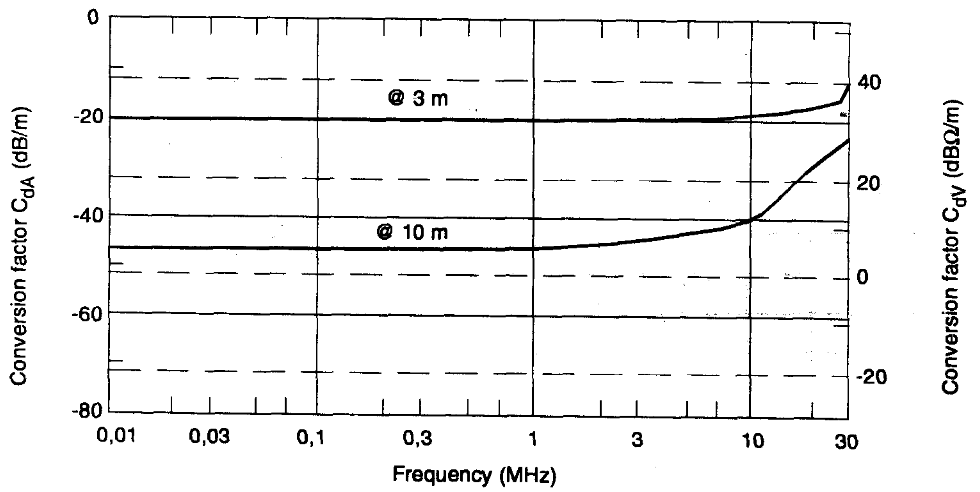


Figure R.10 – Conversion factors C_{dA} (for conversion into dB (µA/m)) and C_{dV} (for conversion into dB (µV/m)) for two standardized measuring distances *d*

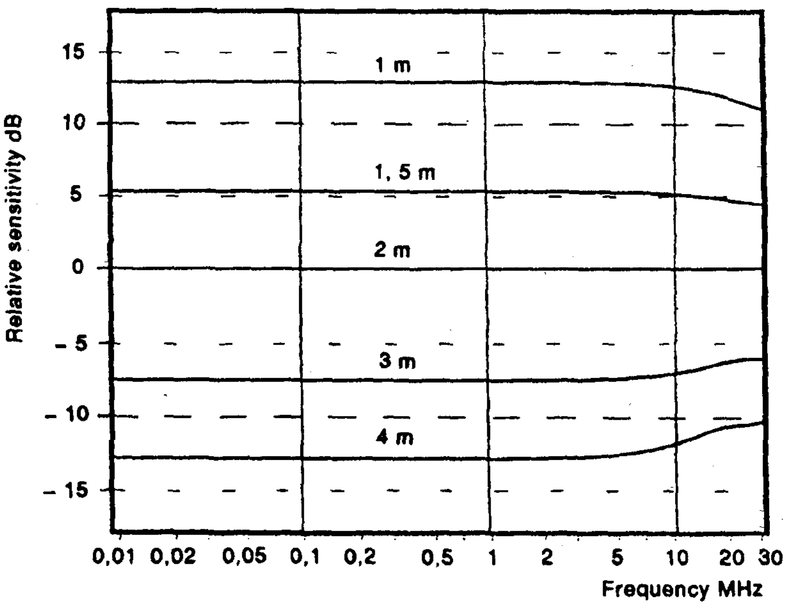


Figure R.11 – Sensitivity S_D of a large-loop antenna with diameter *D* relative to a large-loop antenna having a diameter of 2 m

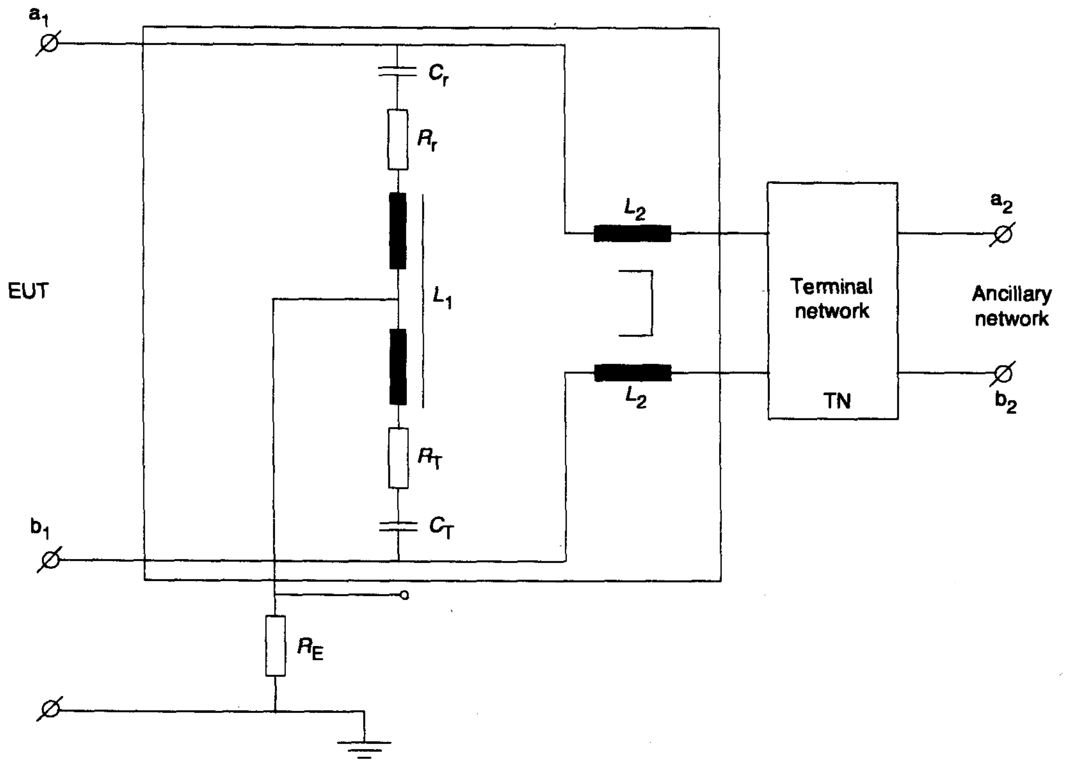


Figure S.1 – Example of a T-network circuit

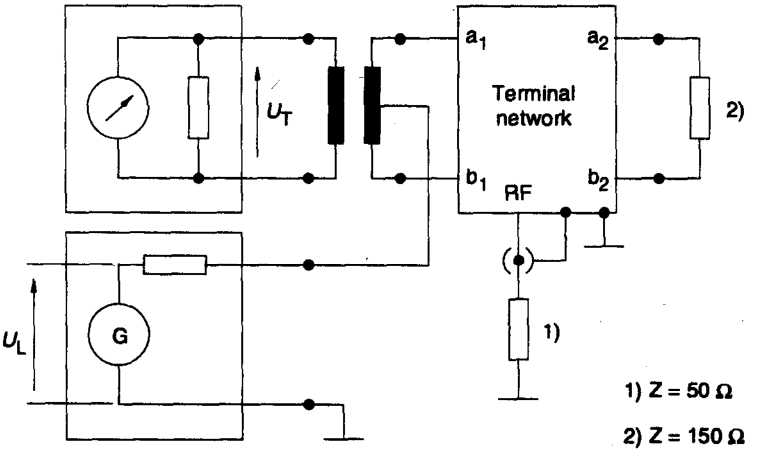
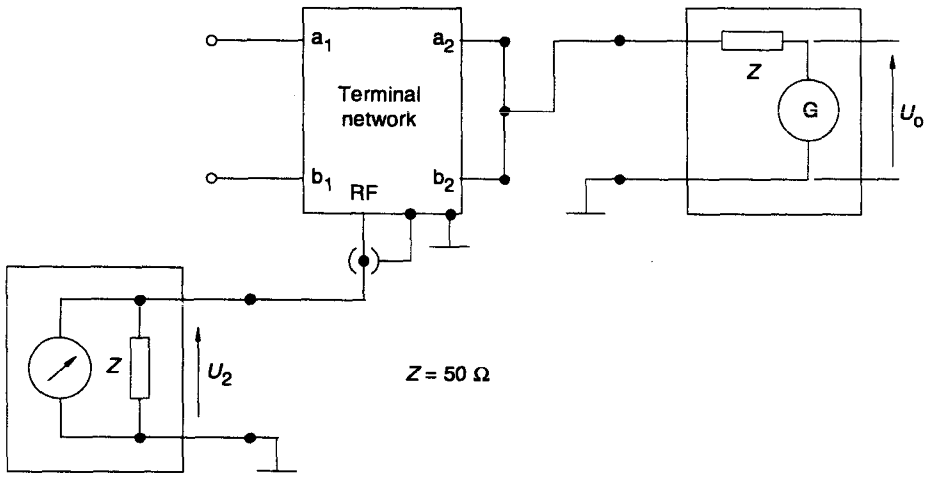
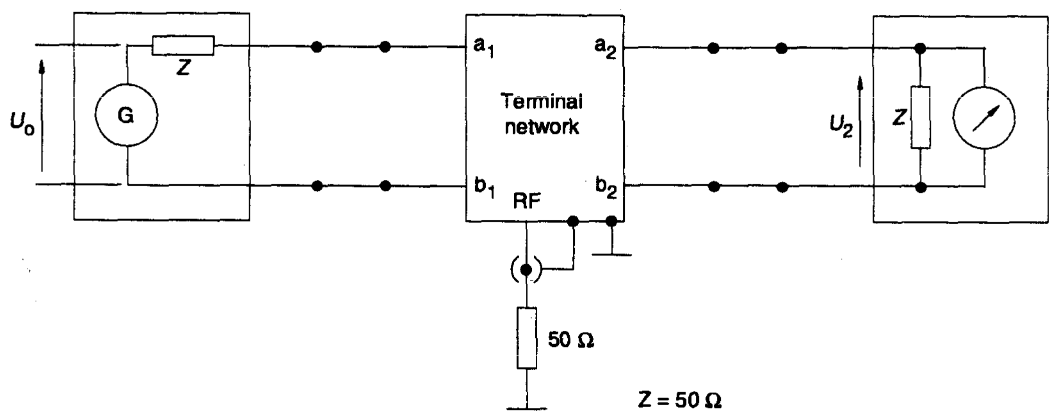


Figure S.2 – T-network test circuit – common mode (unbalanced) rejection



Decoupling attenuation = 20 lg $[U_0/2U_2]$ dB

Figure S.3 – T-network test circuit: decoupling attenuation for asymmetrical signals at the terminals for connection of the ancillary equipment



Insertion loss (sym) = 20 lg $[U_0/2U_2]$ dB

Figure S.4 – T-network test circuit: insertion loss (symmetrical)

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Amendments Issued Since Publication

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