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CISPR 16-2

Second edition
2003-07

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 2: Methods of measurement of disturbances and immunity

Spécification pour les appareils et méthodes de mesure des perturbations radioélectriques et de l'immunité –

Partie 2: Méthodes de mesure des perturbations et de l'immunité

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INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2: Methods of measurement of disturbances and immunity

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International Standard CISPR 16-2 has been prepared by CISPR, subcommittee A: Radio interference measurements and statistical methods.

This second edition cancels and replaces the first edition published in 1996, Amendment 1 (1999) and Amendment 2 (2002).

The document CISPR/A/443/FDIS, circulated to the National Committees as Amendment 3, led to the publication of the new edition.

The text of this standard is based on the first edition, its Amendment 1 and Amendment 2 and on the following documents:

FDIS	Report on voting
CISPR/A/443/FDIS	CISPR/A/463/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

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

This standard should be read in conjunction with CISPR 16-1.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

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- withdrawn;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

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SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2: Methods of measurement of disturbances and immunity

Section 1: General

1.1 Scope

This part of CISPR 16 specifies the methods of measurement of EMC phenomena in the frequency range 9 kHz to 18 GHz.

1.2 Normative references

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

IEC 60083:1997, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC – Standards*

IEC 60364-4: *Electrical installations of buildings – Part 4: Protection for safety*

CISPR 11:1997, *Industrial, scientific and medical (ISM)radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

CISPR 13:2001, *Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement*

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

CISPR 16-1:1999, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

CISPR 22:1997, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

ITU-R Recommendation BS.468-4: *Measurement of audio-frequency noise voltage level in sound broadcasting*

1.3 Definitions

For the purpose of this part of CISPR 16, the definitions of IEC 60050(161) apply, as well as the following:

1.3.1
associated equipment

1) Transducers (e.g. probes, networks and antennas) connected to a measuring receiver or test generator
2) Transducers (e.g. probes, networks, antennas) which are used in the signal or disturbance transfer between an EUT and measuring equipment or a (test-) signal generator

1.3.2
EUT
the equipment (devices, appliances and systems) subjected to EMC (emission and immunity) compliance tests

1.3.3
product publication
publication specifying EMC requirements for a product or product family, taking into account specific aspects of such a product or product family

1.3.4
emission limit (from a disturbing source)
the specified maximum emission level of a source of electromagnetic disturbance

[IEV 161-03-12]

1.3.5
immunity limit
the specified minimum immunity level

[IEV 161-03-15]

1.3.6
ground reference
a connection that constitutes a defined parasitic capacitance to the surrounding of an EUT and serves as reference potential

NOTE See also IEV 161-04-36.

1.3.7
(electromagnetic) emission
the phenomenon by which electromagnetic energy emanates from a source

[IEV 161-01-08]

1.3.8
Immunity (to a disturbance)
the ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[IEV 161-01-20]

1.3.9
coaxial cable
a cable containing one or more coaxial lines, typically used for a matched connection of associated equipment to the measuring equipment or (test-)signal generator providing a specified characteristic impedance and a specified maximum allowable cable transfer impedance

1.3.10
common mode (asymmetrical disturbance voltage)
the RF voltage between the artificial midpoint of a two-conductor line and reference ground, or in case of a bundle of lines, the effective RF disturbance voltage of the whole bundle (vector sum of the unsymmetrical voltages) against the reference ground measured with a clamp (current transformer) at a defined terminating impedance

NOTE See also IEV 161-04-09.

1.3.11
common mode current
the vector sum of the currents flowing through two or more conductors at a specified cross-section of a "mathematical" plane intersected by these conductors

1.3.12
differential mode voltage; symmetrical voltage
the RF disturbance voltage between the wires of a two conductor line

[IEV 161-04-08, modified]

1.3.13
differential mode current
half the vector difference of the currents flowing in any two of a specified set of active conductors at a specified cross-section of a "mathematical" plane intersected by these conductors

1.3.14
unsymmetrical mode (V-terminal voltage)
the voltage between a conductor or terminal of a device, equipment or system and a specified ground reference. For the case of a two-port network, the two unsymmetrical voltages are given by:

a) the vector sum of the asymmetrical voltage and half of the symmetrical voltage; and

b) the vector difference between the asymmetrical voltage and half of the symmetrical voltage.

NOTE See also IEV 161-04-13.

1.3.15
measuring receiver
a receiver for the measurement of disturbances with different detectors

NOTE The receiver is specified according to CISPR 16-1.

1.3.16
test configuration
gives the specified measurement arrangement of the EUT in which an emission or immunity level is measured

NOTE The emission level or immunity level is measured as required by IEV 161-03-11, IEV 161-03-12, IEV 161-03-14 and IEV 161-03-15, definitions of emission level and immunity level.

1.3.17
artificial network (AN)
an agreed reference load (simulation) impedance presented to the EUT by actual networks (e.g., extended power or communication lines) across which the RF disturbance voltage is measured

1.3.18
artificial mains network (AMN)
a network inserted in the supply mains lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which may isolate the apparatus from the supply mains in that frequency range

[IEV 161-04-05]

1.3.19
weighting (quasi-peak detection)
the repetition-rate dependent conversion of the peak-detected pulse voltages to an indication corresponding to the psychophysical annoyance of pulsive disturbances (acoustically or visually) according to the weighting characteristics, or alternatively gives the specified manner in which an emission level or an immunity level is evaluated

NOTE 1 The weighting characteristics are specified in CISPR 16-1.

NOTE 2 The emission level or immunity level is evaluated as required by IEC 60050(161) definitions of level (see IEV 161-03-01, IEV 161-03-11 and IEV 161-03-14).

1.3.20
continuous disturbance
RF disturbance with a duration of more than 200 ms at the IF-output of a measuring receiver, which causes a deflection on the meter of a measuring receiver in quasi-peak detection mode which does not decrease immediately

[IEV 161-02-11, modified]

NOTE The measuring receiver is specified in CISPR 16-1.

1.3.21
discontinuous disturbance
for counted clicks, disturbance with a duration of less than 200 ms at the IF-output of a measuring receiver, which causes a transient deflection on the meter of a measuring receiver in quasi-peak detection mode

NOTE 1 For impulsive disturbance, see IEV 161-02-08.

NOTE 2 The measuring receiver is specified in CISPR 16-1.

1.3.22
fully anechoic chamber (FAC) or fully anechoic room (FAR)
shielded enclosure, the internal surfaces of which are lined with radio frequency absorbing material (i.e. RF absorber), that absorbs electromagnetic energy in the frequency range of interest. The Fully Absorber-Lined Room is intended to simulate a free space environment where only the direct ray from the transmitting antenna reaches the receiving antenna. All indirect and reflected waves are minimised with the use of proper absorbing material on all walls, the ceiling and the floor of the FAR

1.3.23
measurement time
T_m
the effective, coherent time for a measurement result at a single frequency (sometimes also called dwell time)

- for the peak detector, the effective time to detect the maximum of the signal envelope,
- for the quasi-peak detector, the effective time to measure the maximum of the weighted envelope
- for the average detector, the effective time to average the signal envelope
- for the r.m.s. detector, the effective time to determine the r.m.s. of the signal envelope

1.3.24
sweep
a continuous frequency variation over a given frequency span

1.3.25
scan
a continuous or stepped frequency variation over a given frequency span

1.3.26
sweep or scan time
T_s
the time between start and stop frequencies of a sweep or scan

1.3.27
span
Δf
difference between stop and start frequencies of a sweep or scan

1.3.28
sweep or scan rate
the frequency span divided by the sweep or scan time

1.3.29
number of sweeps per time unit (e.g. per second)
n_s
1/(sweep time + retrace time)

1.3.30
observation time
T_o
the sum of measurement times T_m on a certain frequency in case of multiple sweeps. If n is the number of sweeps or scans, then $T_o = n \times T_m$

1.3.31
total observation time
T_{tot}
the effective time for an overview of the spectrum (either single or multiple sweeps). If c is the number of channels within a scan or sweep, then $T_{tot} = c \times n \times T_m$

Section 2: Disturbance measurements

2.1 Types of disturbance to be measured

This subclause describes the classification of different types of disturbance and the detectors appropriate for their measurement.

2.1.1 Types of disturbance

For physical and psychophysical reasons, dependent on the spectral distribution, measuring receiver bandwidth, the duration, rate of occurrence, and degree of annoyance during the assessment and measurement of radio disturbance, distinction is made between the following types of disturbance:

a) *narrowband continuous disturbance*, i.e. disturbance on discrete frequencies as, for example, the fundamentals and harmonics generated with the intentional application of RF energy with ISM equipment, constituting a frequency spectrum consisting only of individual spectral lines whose separation is greater than the bandwidth of the measuring receiver so that during the measurement only one line falls into the bandwidth in contrast to b);

b) *broadband continuous disturbance*, which normally is unintentionally produced by the repeated impulses of, for example, commutator motors, and which have a repetition frequency which is lower than the bandwidth of the measuring receiver so that during the measurement more than one spectral line falls into the bandwidth; and

c) *broadband discontinuous disturbance* is also generated unintentionally by mechanical or electronic switching procedures, for example by thermostats or programme controls with a repetition rate lower than 1 Hz (click-rate less than 30/min).

The frequency spectra of b) and c) are characterized by having a continuous spectrum in the case of individual (single) impulses and a discontinuous spectrum in case of repeated impulses, both spectra being characterized by having a frequency range which is wider than the bandwidth of the measuring receiver specified in CISPR 16-1.

2.1.2 Detector functions

Depending on the types of disturbance, measurements may be carried out using a measuring receiver with:

a) an average detector generally used in the measurement of narrowband disturbance and signals, and particularly to discriminate between narrowband and broadband disturbance;

b) a quasi-peak detector provided for the weighted measurement of broadband disturbance for the assessment of audio annoyance to a radio listener, but also usable for narrowband disturbance;

c) a peak detector which may be used for either broadband or narrowband disturbance measurement.

Measuring receivers incorporating these detectors are specified in CISPR 16-1.

2.2 Connection of measuring equipment

This subclause describes the connection of measuring equipment, measuring receivers and associated equipment such as artificial networks, voltage and current probes, absorbing clamps and antennas.

2.2.1 Connection of associated equipment

The connecting cable between the measuring receiver and the associated equipment shall be shielded and its characteristic impedance shall be matched to the input impedance of the measuring receiver.

The output of the associated equipment shall be terminated with the prescribed impedance.

2.2.2 Connections to RF reference ground

The artificial mains network (AMN) shall be connected to the reference ground by a low RF impedance, e.g. by direct bonding of the case of the AMN to the reference ground or reference wall of a shielded room, or with a low impedance conductor as short and as wide as practical (maximum length to width ratio is 3:1).

Terminal voltage measurements shall be referenced only to the reference ground. Ground loops (common impedance coupling) shall be avoided. This should also be observed for measuring apparatus (e.g. measuring receivers and connected associated equipment, such as oscilloscopes, analyzers, recorders, etc.) fitted with a protective earth conductor (PE) of Protection Class I equipment. If the PE connection of the measuring apparatus and the PE connection of the power mains to the reference ground do not have RF isolation from the reference ground, the necessary RF isolation shall be provided by means such as RF chokes and isolation transformers, or if applicable, by powering the measuring apparatus from batteries, so that the RF connection of the measuring apparatus to the reference ground is made via only one route.

For the treatment of PE connection of the EUT to the reference ground, see Clause A.4.

Stationary test configurations do not require a connection with the protective earth conductor if the reference ground is connected directly and meets the safety requirements for protective earth conductors (PE connections).

2.2.3 Connection between the EUT and the artificial mains network

General guidelines for the selection of grounded and non-grounded connections of the EUT to the AMN are discussed in Annex A.

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2.3 General measurement requirements and conditions

Radio disturbance measurements shall be:

a) reproducible, i.e. independent of the measurement location and environmental conditions, especially ambient noise;

b) free from interactions, i.e. the connection of the EUT to the measuring equipment shall neither influence the function of the EUT nor the accuracy of the measurement equipment.

These requirements may be met by observing the following conditions:

c) existence of a sufficient signal-to-noise ratio at the desired measurement level, e.g. the level of the relevant disturbance limit;

d) having a defined measuring set-up, termination and operating conditions of the EUT;

e) having a sufficiently high impedance of the probe at the measuring point, in the case of voltage probe measurements;

f) when using a spectrum analyzer or scanning receiver due considerations shall be given to its particular operating and calibration requirements.

2.3.1 Disturbance not produced by the equipment under test

The measurement signal-to-noise ratio with respect to ambient noise shall meet the following requirements. Should the spurious noise level exceed the required level, it shall be recorded in the test report.

2.3.1.1 Compliance testing

A test site shall permit emissions from the EUT to be distinguished from ambient noise. The ambient noise level should preferably be 20 dB, but at least be 6 dB below the desired measurement level. For the 6 dB condition, the apparent disturbance level from the EUT is increased by up to 3,5 dB. The suitability of the site for required ambient level may be determined by measuring the ambient noise level with the test unit in place but not operating.

In the case of compliance measurement according to a limit, the ambient noise level is permitted to exceed the preferred –6 dB level provided that the level of both ambient noise and source emanation combined does not exceed the specified limit. The EUT is then considered to meet the limit. Other actions can also be taken; for example, reduce the bandwidth for narrowband signals and/or move the antenna closer to the EUT.

NOTE If both the ambient field strength and field strength of ambient and EUT are measured separately, it may be possible to provide an estimate of the EUT field strength to a quantifiable level of uncertainty. Reference is made in this respect in Annex E of this standard and in Annex C of CISPR 11.

2.3.2 Measurement of continuous disturbance

2.3.2.1 Narrowband continuous disturbance

The measuring set shall be kept tuned to the discrete frequency under investigation and returned if the frequency fluctuates.

2.3.2.2 Broadband continuous disturbance

For the assessment of broadband continuous disturbance the level of which is not steady, the maximum reproducible measurement value shall be found. See 2.3.4.1 for further details.

2.3.2.3 Use of spectrum analyzers and scanning receivers

Spectrum analyzers and scanning receivers are useful for disturbance measurements, particularly in order to reduce measuring time. However, special consideration must be given to certain characteristics of these instruments, which include: overload, linearity, selectivity, normal response to pulses, frequency scan rate, signal interception, sensitivity, amplitude accuracy and peak, average and quasi-peak detection. These characteristics are considered in Annex B.

2.3.3 Operating conditions of the EUT

The EUT shall be operated under the following conditions:

2.3.3.1 Normal load conditions

The normal load conditions shall be as defined in the product specification relevant to the EUT, and for EUTs not so covered, as indicated in the manufacturer's instructions.

2.3.3.2 The time of operation

The time of operation shall be, in the case of EUTs with a given rated operating time, in accordance with the marking; in all other cases, the time is not restricted.

2.3.3.3 Running-in time

No specific running-in time, prior to testing, is given, but the EUT shall be operated for a sufficient period to ensure that the modes and conditions of operation are typical of those during the life of the equipment. For some EUTs, special test conditions may be prescribed in the relevant equipment publications.

2.3.3.4 Supply

The EUT shall be operated from a supply having the rated voltage of the EUT. If the level of disturbance varies considerably with the supply voltage, the measurements shall be repeated for supply voltages over the range of 0,9 to 1,1 times the rated voltage. EUTs with more than one rated voltage shall be tested at the rated voltage which causes maximum disturbance.

2.3.3.5 Mode of operation

The EUT shall be operated under practical conditions which cause the maximum disturbance at the measurement frequency.

2.3.4 Interpretation of measuring results

2.3.4.1 Continuous disturbance

a) If the level of disturbance is not steady, the reading on the measuring receiver is observed for at least 15 s for each measurement; the highest readings shall be recorded, with the exception of any isolated clicks, which shall be ignored (see 4.2 of CISPR 14-1).

b) If the general level of the disturbance is not steady, but shows a continuous rise or fall of more than 2 dB in the 15 s period, then the disturbance voltage levels shall be observed for a further period and the levels shall be interpreted according to the conditions of normal use of the EUT, as follows:

   1) if the EUT is one which may be switched on and off frequently, or the direction of rotation of which can be reversed, then at each frequency of measurement the EUT should be switched on or reversed just before each measurement, and switched off just after each measurement. The maximum level obtained during the first minute at each frequency of measurement shall be recorded;

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2) if the EUT is one which in normal use runs for longer periods, then it should remain switched on for the period of the complete test, and at each frequency the level of disturbance shall be recorded only after a steady reading (subject to the provision that item a) has been obtained).

c) If the pattern of the disturbance from the EUT changes from a steady to a random character part way through a test, then that EUT shall be tested in accordance with item b).

d) Measurements are taken throughout the complete spectrum and are recorded at least at the frequency with maximum reading and as required by the relevant CISPR publication.

2.3.4.2 Discontinuous disturbance

Measurement of discontinuous disturbance may be performed at a restricted number of frequencies. For further details, see CISPR 14-1.

2.3.4.3 Measurement of the duration of disturbances

The EUT is connected to the relevant artificial mains network. If a measuring set is available, it is connected to the network and a cathode-ray oscilloscope is connected to the intermediate frequency (i.f.) output of the measuring set. If a receiver is not available, the oscilloscope is connected directly to the network. The time base of the oscilloscope can be started by the disturbances to be tested; the time base is set to a value of 1 ms/div –10 ms/div for EUT with instantaneous switching and 10 ms/div – 200 ms/div for other EUT. The duration of the disturbance can either be recorded directly by a storage oscilloscope or digital oscilloscope or by photograph or hard copy recording of the screen.

2.3.5 Measurement times and scan rates for continuous disturbance

Both for manual measurements and automated or semiautomated measurements, measurement times and scan rates of measuring and scanning receivers shall be set so as to measure the maximum emission. Especially, where a peak detector is used for prescans, the measurement times and scan rates have to take the timing of the emission under test into account. More detailed guidance on the execution of automated measurements can be found in 4.1.

2.3.5.1 Minimum measurement times

Clause B.7 of the present standard provides a table of the minimum sweep times or the fastest – practically achievable – scan rates. From this table the following minimum scan times for measurements over a complete CISPR band have been derived:

Table 1 – Minimum scan times for the three CISPR bands with peak and quasi-peak detectors

Frequency band		Scan time T_s for peak detection	Scan time T_s for quasi-peak detection
A	9 kHz – 150 kHz	14,1 s	2820 s = 47 min
B	0,15 MHz – 30 MHz	2,985 s	5 970 s = 99,5 min = 1 h 39 min
C/D	30 MHz – 1 000 MHz	0,97 s	19 400 s = 323,3 min = 5 h 23 min

The scan times in Table 1 apply to the measurement of CW signals. Depending on the type of disturbance, the scan time may have to be increased – even for quasi-peak measurements. In extreme cases, the measurement time T_m at a certain frequency may have to be increased to 15 s, if the level of the observed emission is not steady (see 2.3.4.1). However isolated clicks are excluded.

Most product standards call out quasi-peak detection for compliance measurements which is very time consuming, if no time-saving procedures are applied (see 4.1). Before time-saving procedures can be applied, the emission has to be detected in a prescan. In order to ensure that e.g. intermittent signals are not missed during an automatic scan, the considerations in 2.3.5.2 to 2.3.5.4 need to be taken into account.

2.3.5.2 Scan rates for scanning receivers and spectrum analyzers

One of two conditions need to be met to ensure that signals are not missed during automatic scans over frequency spans:

1) for a single sweep: the measurement time at each frequency must be larger than the intervals between pulses for intermittent signals;
2) for multiple sweeps with maximum hold: the observation time at each frequency should be sufficient for intercepting intermittent signals.

The frequency scan rate is limited by the instrument's resolution bandwidth and the video bandwidth setting. If the scan rate is chosen too fast for the given instrument state, erroneous measurement results will be obtained. Therefore, a sufficiently long sweep time needs to be chosen for the selected frequency span. Intermittent signals may be intercepted by either a single sweep with sufficient observation time at each frequency or by multiple sweeps with maximum hold. Usually for an overview over unknown emissions, the latter will be highly efficient: as long as the spectrum display changes, there may still be intermittent signals to discover. The observation time has to be selected according to the periodicity at which interfering signals occur. In some cases, the sweep time may have to be varied in order to avoid synchronization effects.

When determining the minimum sweep time for measurements with a spectrum analyzer or scanning EMI receiver, based on a given instrument setting and using peak detection, two different cases have to be distinguished. If the video bandwidth is selected to be **wider** than the resolution bandwidth, the following expression can be used to calculate the minimum sweep time:

$$T_{\mathrm{s\ min}} = (\mathrm{k} \times \Delta f) \,/\, (B_{\mathrm{res}})^2 \qquad (1)$$

where

$T_{\mathrm{s\ min}}$ = Minimum sweep time

Δf = Frequency span

B_{res} = Resolution bandwidth

k = Constant of proportionality, related to the shape of the resolution filter; this constant assumes a value between 2 and 3 for synchronously-tuned, near-Gaussian filters. For nearly rectangular, stagger-tuned filters, k has a value between 10 and 15.

If the video bandwidth is selected to be equal to or smaller than the resolution bandwidth, the following expression can be used to calculate the minimum sweep time:

$$T_{\mathrm{s\ min}} = (\mathrm{k} \times \Delta f) \,/\, (B_{\mathrm{res}} \times B_{\mathrm{video}}) \qquad (2)$$

where B_{video} = Video bandwidth

Most spectrum analyzers and scanning EMI receivers automatically couple the sweep time to the selected frequency span and the bandwidth settings. Sweep time is adjusted to maintain a calibrated display. The automatic sweep time selection can be overridden if longer observation times are required, e.g., to intercept slowly varying signals.

In addition, for repetitive sweeps, the number of sweeps per second will be determined by the sweep time $T_{s\ min}$ and the retrace time (time needed to retune the local oscillator and to store the measurement results, etc.).

2.3.5.3 Scan times for stepping receivers

Stepping EMI receivers are consecutively tuned to single frequencies using predefined step sizes. While covering the frequency range of interest in discrete frequency steps, a minimum dwell time at each frequency is required for the instrument to accurately measure the input signal.

For the actual measurement, a frequency step size of roughly 50 % of the resolution bandwidth used or less (depending on the resolution filter shape) is required to reduce measurement uncertainty for narrowband signals due to the stepwidth. Under these assumptions the scan time $T_{s\ min}$ for a stepping receiver can be calculated using the following equation:

$$T_{s\ min} = T_{m\ min} \times \Delta f/(B_{res} \times 0{,}5) \tag{3}$$

where $T_{m\ min}$ = Minimum measurement (dwell) time at each frequency

In addition to the measurement time, some time has to be taken into consideration for the synthesizer to switch to the next frequency and for the firmware to store the measurement result, which in most measuring receivers is automatically done so that the selected measurement time is the effective time for the measurement result. Furthermore, the selected detector, e.g. peak or quasi-peak, determines this time period as well.

For purely broadband emissions, the frequency step size may be increased. In this case the objective is to find the maxima of the emission spectrum only.

2.3.5.4 Strategies for obtaining a spectrum overview using the peak detector

For each prescan measurement, the probability of intercepting all critical spectral components of the EUT spectrum shall be equal to 100 % or as close to 100 % as possible. Depending on the type of measuring receiver and the characteristics of the disturbance, which may contain narrowband and broadband components, two general approaches are proposed:

– stepped scan: the measurement (dwell) time shall be long enough at each frequency to measure the signal peak, e.g. for an impulsive signal the measurement (dwell) time should be longer than the reciprocal of the repetition frequency of the signal.
– swept scan: the measurement time must be larger than the intervals between intermittent signals (single sweep) and the number of frequency scans during the observation time should be maximized to increase the probability of signal interception.

Figures 1, 2 and 3 show examples of the relationship between various time-varying emission spectra and the corresponding display on a measuring receiver. In each case the upper part of the figure shows the position of the receiver bandwidth as it either sweeps or steps through the spectrum.

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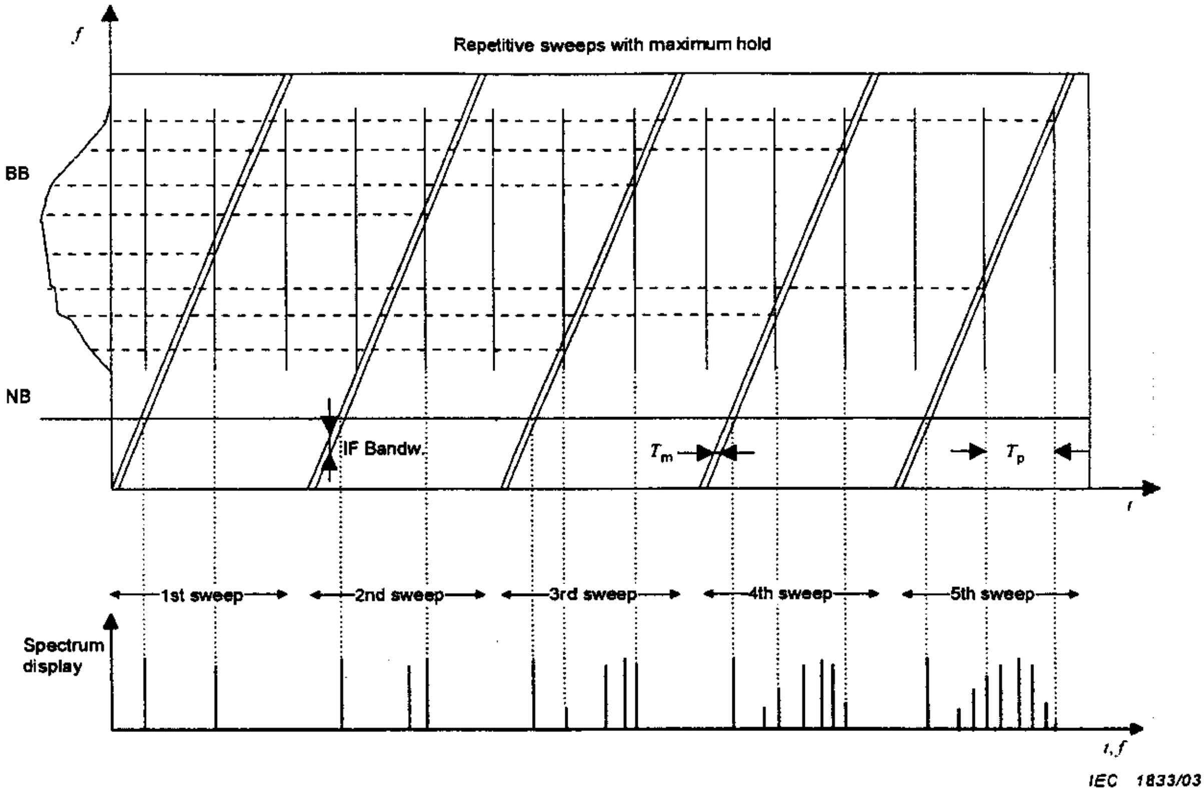

T_p is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum-vs.-time display (upper part of the figure).

Figure 1 – Measurement of a combination of a CW signal ("NB") and an impulsive signal ("BB") using multiple sweeps with maximum hold

If the type of emission is unknown, multiple sweeps with the shortest possible sweep time and peak detection allow to determine the spectrum envelope. A short single sweep is sufficient to measure the continuous narrowband signal content of the EUT spectrum. For continuous broadband and intermittent narrowband signals, multiple sweeps at various scan rates using a "maximum hold" function may be necessary to determine the spectrum envelope. For low repetition impulsive signals, many sweeps will be necessary to fill up the spectrum envelope of the broadband component.

The reduction of measurement time requires a timing analysis of the signals to be measured. This can be done either with a measuring receiver which provides a graphical signal display, used in zero-span mode or using an oscilloscope connected to the receiver's IF or video output as e.g. shown in Figure 2.

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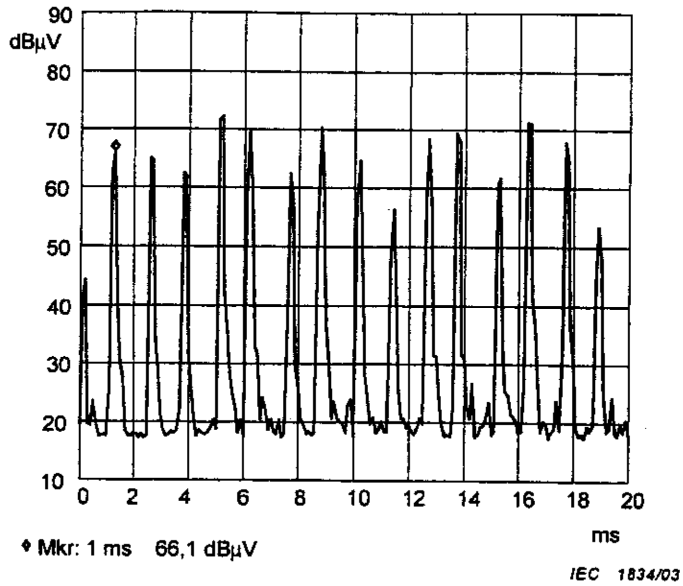

Disturbance from a DC collector motor: due to the number of collector segments the pulse repetition frequency is high (approx. 800 Hz) and the pulse amplitude varies strongly. Therefore for this example, the recommended measurement (dwell) time with the peak detector is > 10 ms.

Figure 2 – Example of a timing analysis

This way pulse durations and pulse repetition frequencies can be determined and scan rates or dwell times selected accordingly:

– for **continuous unmodulated narrowband** disturbances the fastest scan time possible for the selected instrument settings may be used;

– for **pure continuous broadband** disturbances, e.g. from ignition motors, arc welding equipment, and collector motors, a stepped scan (with peak or even quasi-peak detection) for sampling of the emission spectrum may be used. In this case the knowledge of the type of disturbance is used to draw a polyline curve as the spectrum envelope (see Figure 3). The step size has to be chosen so that no significant variations in the spectrum envelope are missed. A single swept measurement – if performed slowly enough – will also yield the spectrum envelope;

– for **intermittent narrowband** disturbances with unknown frequencies either fast short sweeps involving a "maximum hold" function (see Figure 4) or a slow single sweep may be used. A timing analysis may be required prior to the actual measurement to ensure proper signal interception.

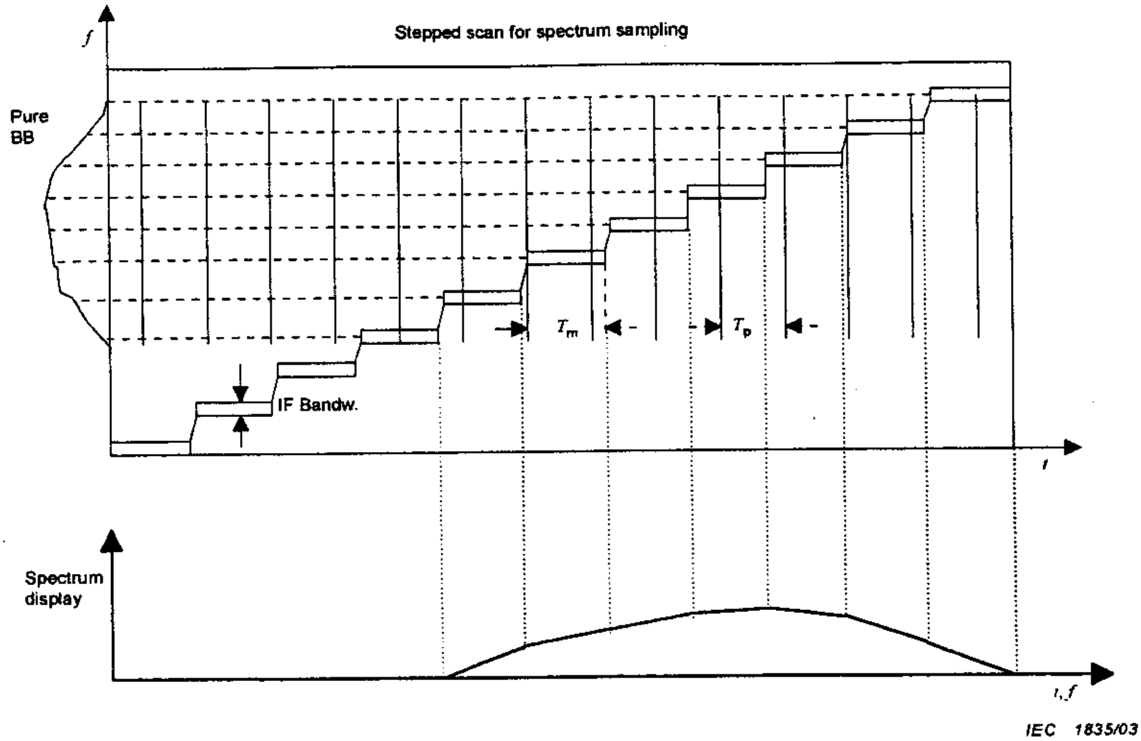

Figure 3 – A broadband spectrum measured with a stepped receiver

The measurement (dwell) time T_m should be longer than the pulse repetition interval T_p, which is the inverse of the pulse repetition frequency.

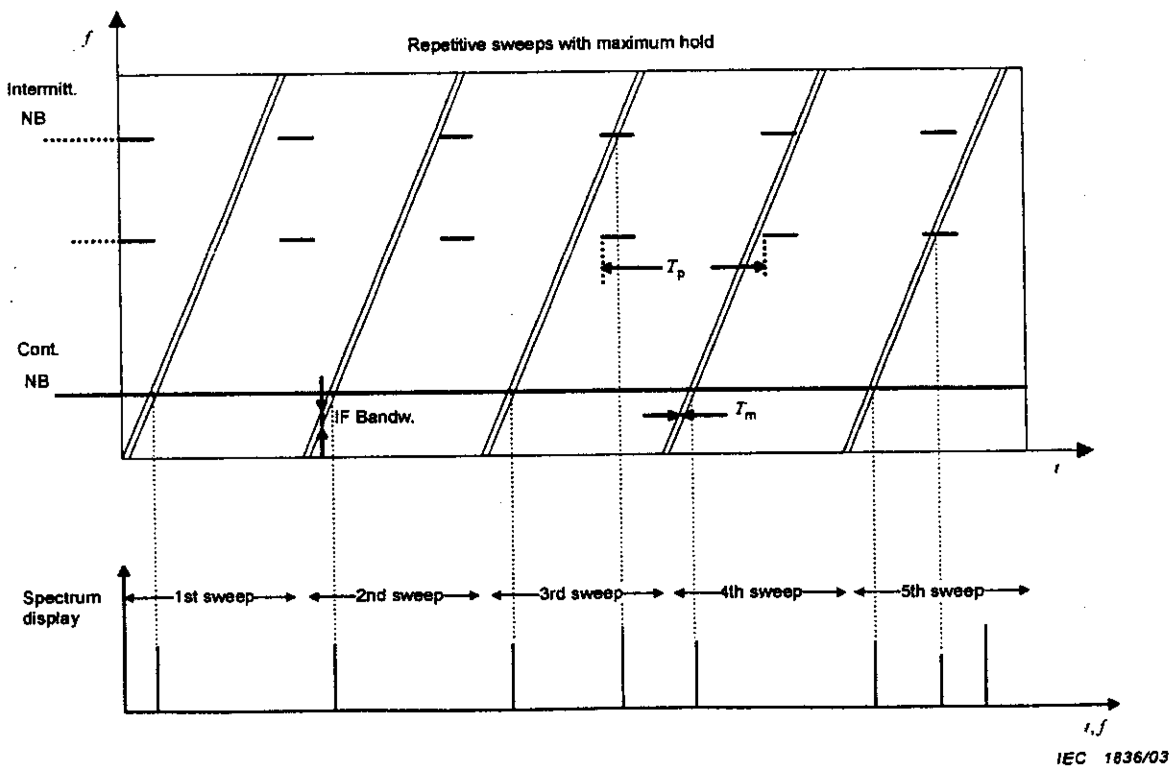

Figure 4 – Intermittent narrowband disturbances measured using fast short repetitive sweeps with maximum hold function to obtain an overview of the emission spectrum

NOTE In the example above, 5 sweeps are required until all spectral components are intercepted. The number of sweeps required or the sweeptime may have to be increased, depending on pulse duration and pulse repetition interval.

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Intermittent broadband disturbances have to be measured with discontinuous disturbance analysis procedures, as described in Part 1 of this standard.

2.4 Measurement of disturbances conducted along leads, 9 kHz to 30 MHz

2.4.1 Introduction

When testing for compliance with emission limits for electromagnetic disturbances conducted along leads, the following items shall be considered as minimum, both in the standardized situation (type tests) and at the place of installation (*in situ* tests):

a) *the types of disturbances:* there are two methods of measuring conducted disturbances, either as a voltage (prevailing method for CISPR measurements) or as a current. Both methods can be used to measure the three types of conducted disturbances, i.e:
   - common mode (also called asymmetrical mode);
   - differential mode (also called symmetrical mode);
   - unsymmetrical mode;

   NOTE The unsymmetrical mode voltage is primarily measured at the mains network. The common mode voltage (or current) is measured primarily for signal and control lines.

b) *the measuring equipment:* the type of measuring equipment is chosen in relation to the disturbance properties to be determined (see 2.4.2);

c) *the associated equipment:* the type of associated equipment, i.e., artificial networks, current probes or voltage probes, is chosen in accordance with the type of disturbance to be measured in accordance with 2.4.1 a). Each type of associated equipment presents RF loading to the measured signals and lines (see 2.4.3);

d) *RF load conditions of the disturbance source:* the measuring set-up will present certain RF load impedances to the disturbance source(s) in the EUT. These impedances are standardized in type tests or might depend on the conditions at the place of installation in the case of *in situ* tests (see 2.4.3 and 2.4.4);

e) *the test configuration of EUT:* a standardized test configuration shall specify the reference ground, the position of the EUT and associated measuring equipment with respect to that reference ground, connections to that reference ground and interconnections of the EUT with the associated equipment (see 2.4.4 and 2.4.5).

2.4.2 Measuring equipment (receivers, etc.)

In general, a distinction is drawn between continuous and discontinuous disturbances. Continuous radio-frequency disturbances are predominantly measured in terms of frequency domain parameters. Discontinuous disturbances are also measured in terms of frequency domain parameters but may need additional time domain measurements.

The measuring sets and other measuring equipment specified in CISPR 16-1 shall be used. For time domain measurements oscilloscopes etc. may be used.

2.4.2.1 Use of detectors for conducted disturbance measurements

CISPR 16-1 specifies the characteristics of detectors that are required to perform measurements per product specifications. Several of these product specifications require the use of both quasi-peak and average detectors for conducted disturbance measurements. The time constants of these two detectors are very long and make automated measurements time consuming.

A peak detector with shorter time constants may be used to make initial measurements and to determine compliance with a limit. But if the measured disturbance levels are above a limit they shall be followed by measurements with the quasi-peak and average detectors.

Annex D provides guidance on how these measurements may be performed efficiently.

2.4.3 Associated measuring equipment

Associated measuring equipment for conducted disturbance measurement is divided into two categories:

a) voltage measuring sensors, such as artificial networks (AN) and voltage probes;

NOTE The artificial network is sometimes referred to as impedance simulation network (ISN).

b) current measuring sensors, such as current probes.

2.4.3.1 Artificial networks (AN)

The common mode, differential and unsymmetrical mode impedances of actual networks, such as of power mains and telephones, are location dependent and, in general, time varying. Therefore, type testing of disturbance requires standardized impedance simulation networks, referred to as artificial networks (AN). The AN provides standardized RF load impedances to the EUT. For this purpose, the AN is inserted in series with the terminals of the EUT and the actual network or signal simulator. In this way the AN simulates extended networks (long lines) with defined impedances.

2.4.3.1.1 Types of artificial networks

The ANs specified in CISPR 16-1 shall be used, unless specific reasons call for another construction. In general three types of AN can be distinguished:

a) *the V-type AN:* in a defined frequency range the RF impedances between each of the EUT terminals to be measured and the reference ground have a defined value, whereas no impedance component is connected directly between these terminals. The construction defines (indirectly) both the differential and common mode voltage measured. In principle, there is no limit for the number of EUT terminals, i.e. for the number of lines to be measured by V-type ANs;

b) *the Delta-type AN:* in a defined frequency range the RF impedance between a pair of EUT terminals to be measured and between these terminals and the reference ground have a defined value. This construction defines directly both the differential and the common mode RF load impedances.

   Addition of a balance/unbalance transformer makes it possible to measure the symmetric and asymmetric disturbance voltage;

c) *the T-type AN:* in a defined frequency range the common mode RF impedance between a pair of EUT terminals to be measured and a reference ground has a defined value. In general, no defined differential load impedance is included in a T-type AN as such. The defined differential impedance must then be provided by the external circuit connected to the supply (line) terminals of the T-type AN. This type of AN is used to measure common mode disturbance voltages only.

2.4.3.1.2 Minimum requirements

The AN shall meet the following minimum requirements:

a) in a defined frequency range the AN shall provide defined RF impedances between the terminals of the EUT to be measured and between these terminals and the reference ground. By meeting this requirement, the disturbance source to be measured is loaded in a defined manner if, in addition, the test configuration (see 2.4.4) is defined;

b) if the AN is intended to separately measure common mode and/or differential mode disturbances (see 2.4.3.1.1), the rejection ratio of differential to common mode signals, and vice versa, shall be specified in the appropriate frequency range;

c) in a defined frequency range there shall normally be an isolation between the defined RF impedances and the actual network (or a signal simulator) so that the loading of the AN by the actual network (or the signal simulator) does not unduly influence the value of any of the defined RF impedances;

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d) the AN shall provide a defined connection (connector) to which the defined measuring equipment can be connected, in order to make a defined test configuration possible. The input connector shall be suitable for measuring equipment with 50 Ω input impedance as defined in CISPR 16-1;

e) the AN shall provide a defined connecting point to which the reference ground can be connected, in order to make a defined test configuration possible;

f) the AN shall be calibrated according to a prescribed procedure.

2.4.3.1.3 Additional requirements

The AN shall have the following additional requirements:

a) the AN shall contain a decoupling or blocking network to prevent:
   - damage of the components forming the defined RF impedances by the wanted line voltages of the network, such as the mains voltage,
   - damage of the components forming the defined RF impedances by peak voltages produced by the EUT, such as switching transients,
   - influence of the rated line voltages on the measuring results, for example overload of the input stage of the measuring equipment;

b) the AN shall contain a filter to prevent intentional signals on the actual network or the signal simulator influencing the measuring results.

2.4.3.2 Voltage probes

For standardized voltage probes, see CISPR 16-1.

Disturbance voltages on terminals which are not to be measured with an AN can be measured with a voltage probe. Examples of such terminals are connecting jacks for antennas, control lines, signal lines and load lines. In general the voltage probe is used to measure the common mode disturbance voltage. The probe presents a high RF impedance between the terminal to be measured and the reference ground.

2.4.3.2.1 Minimum requirements

a) In a defined frequency range the voltage probe shall provide a high RF impedance between its measuring tip and the reference ground so as not to affect the voltage to be measured.

b) The voltage probe shall have a blocking capacitor of such a value to ensure that line voltage cannot damage the measuring receiver.

c) The voltage probe shall provide a defined 50 Ω connection (connector) to which the standardized measuring receiver can be connected, in order to make a defined disturbance measurement.

d) The voltage probe shall provide a defined connection point to which the reference ground can be connected in a defined manner via a lead of defined maximum length unless the reference ground is connected to the EUT in another specified way.

e) The voltage probe shall be calibrated according to a prescribed procedure, where this procedure shall account for parasitic effects near the test point, for example unwanted capacitive coupling between the test point and the screening of the probe. The voltage division between probe impedance and input impedance of measuring equipment shall be independent of frequency or accounted for in the calibration process.

f) The voltage probe name-plate shall state the maximum line voltage.

2.4.3.3 Current probes

Current probes or current transformers allow the measurement of all three types of disturbance current (see 2.4.1) on mains leads, signal lines, load lines etc. A clip-on construction of the probe will facilitate its use.

The common mode current on leads is measured when the current probe is clipped around those leads, regardless of the number of wires. In this situation, the differential mode currents on the leads will induce signals with equal magnitude but opposite sign, so that these signals cancel to a high degree. The latter effect allows the measurement of a common mode current with a small amplitude in the presence of differential mode (operating) currents with large amplitude.

For already defined (and standardized) current probes see CISPR 16-1.

2.4.3.3.1 Minimum requirements

a) In a defined frequency range the current probe shall have a defined transfer impedance, that is, a defined ratio of the RF voltage induced in the probe and the known RF current on a single wire running through the probe, as measured in a specified way.

b) In a defined frequency range the insertion loss caused by the current probe, that is of the EUT, shall be less than 1 Ω.

c) The current probe shall be constructed in such a way that the influence of electric fields on the measuring results can be neglected.

d) The current probe shall provide a defined connection (connector) to which the defined (and standardized) measuring equipment can be connected, in order to make a defined test configuration possible. In addition, the input impedance of the measuring equipment to be used in connection with the current probe shall be indicated.

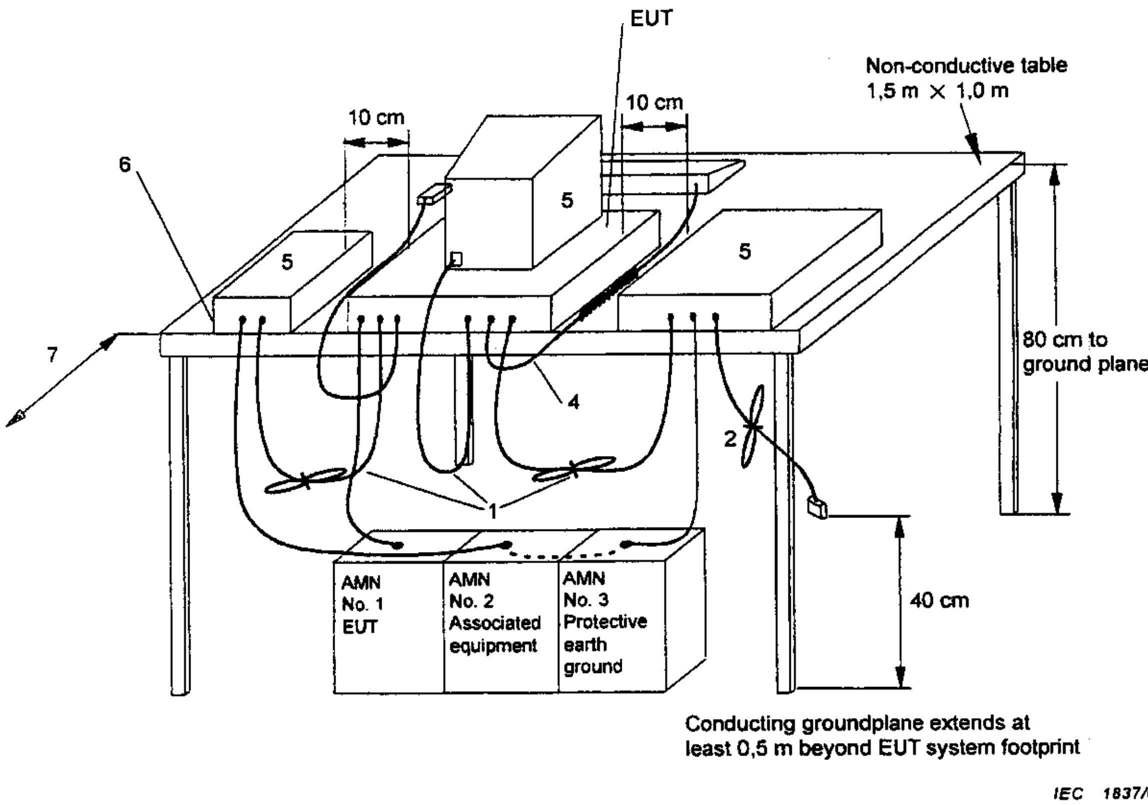
e) The current probe specification shall include the maximum current rating before saturation effects will take place.

f) The current probe shall be calibrated according to a prescribed procedure.

2.4.4 Equipment test configuration

2.4.4.1 Disposition of equipment under test and its connection to the artificial network

For measurement of the disturbance voltage the equipment under test (EUT) is connected to the power supply mains and any other extended network via one or more artificial network(s) (in general, the V-type network is used for this purpose) (see Figure 5), in accordance with the following requirements. Other CISPR publications supply additional test details relevant to particular EUTs.



1 Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth forming a bundle 30 cm to 40 cm long, hanging approximately in the middle between the ground plane and the table.

2 I/O cables that are connected to a peripheral shall be bundled in the centre. The end of the cable may be terminated if required using correct terminating impedance. The total length shall not exceed 1 m.

3 EUT is connected to AMN No 1. Measurement terminals of AMNs must be terminated with 50 Ω. AMNs are placed directly on horizontal ground plane and 40 cm from vertical ground plane.

3.1 All associated equipment is connected to AMN No 2.

3.2 Protective earth ground wires (green/yellow) from associated equipment are connected to AMN No 3.

4 Cables of hand-operated devices, such as keyboards, mouses, etc. shall be placed as close as possible to the host.

5 Non-EUT components being tested.

6 Rear of EUT, including peripherals, shall all be aligned and flush with rear of table top.

7 Rear of table top shall be 40 cm removed from a vertical conducting plane that is bonded to the floor ground plane.

Figure 5 – Test configuration: table-top equipment for conducted disturbance measurements on power mains (see 2.4.4.1 and 2.4.4.2)

An EUT, whether intended to be grounded or not, and which is to be used on a table is configured as follows:

– either the bottom or the rear of the EUT shall be at a controlled distance of 40 cm from a reference groundplane. This groundplane is normally the wall or floor of a shielded room. It may also be a grounded metal plane of at least 2 m by 2 m. This is physically accomplished as follows:

  - place the EUT on a table of non-conducting material which is at least 80 cm high. Place the EUT so that it is 40 cm from the wall of the shielded room, or
  - place the EUT on a table of non-conducting material which is 40 cm high so that the bottom of the EUT is 40 cm above the groundplane;

– all other conductive surfaces of the EUT shall be at least 80 cm from the reference groundplane;

– the ANs are placed on the floor as shown in Figure 5 in such a way that one side of the AN housings is 40 cm from the vertical reference ground plane and other metallic parts;
– the EUT cable connections shall be as shown in Figure 5;
– the optional test configuration for table-top EUT with only a power cord attached is shown in Figure 6.

Floor-standing EUTs are subject to the same provisions as above with the exception that they shall be placed on a floor, the points of contact being consistent with normal use. A ground-connected floor of metal shall be used but shall not make metallic contact with the floor support(s) of the EUT. The metal floor may be used as the reference ground plane and shall extend at least 50 cm beyond the boundaries of the EUT and have minimum dimensions of 2 m by 2 m. For examples of test configurations, see Figures 7 and 8.

The artificial network is RF bonded to the reference groundplane by a low radio-frequency impedance connection.

NOTE The "low" radio-frequency impedance value should preferably be less than 10 Ω at 30 MHz. This can, for example, be achieved if the housing of the artificial network is mounted directly to the reference ground plane or its connection strap has a length-to-width ratio not more than 3:1.

The EUT is located so that the distance between the boundary of it and the closest surface of the artificial network is 80 cm.

The power mains leads to an artificial network and the connecting cable from the network to the measuring receiver must be arranged in such a way that their locations do not influence the measurement results. EUTs, which are not equipped with fixed connecting leads, are connected to the artificial network with a 1 m long lead as specified in the relevant equipment documentation.

If the EUT is to be connected to a reference ground this shall be done by means of a lead running parallel to the EUT mains lead and of the same length at a distance of not more than 10 cm from it, unless a ground conductor is contained in the mains lead itself. If a fixed lead is attached to the EUT this shall be 1 m long, or if in excess of 1 m, part of the lead is folded back and forth in the shape of a meander, as far as possible so as to form a bundle not exceeding 40 cm in length, and arranged in the form of a non-inductive serpentine in such a way that the total length of the lead does not exceed 1 m (see also Figure 9). However, when the bundled lead may influence the measurement results, a shortening of the length to 1 m is recommended.

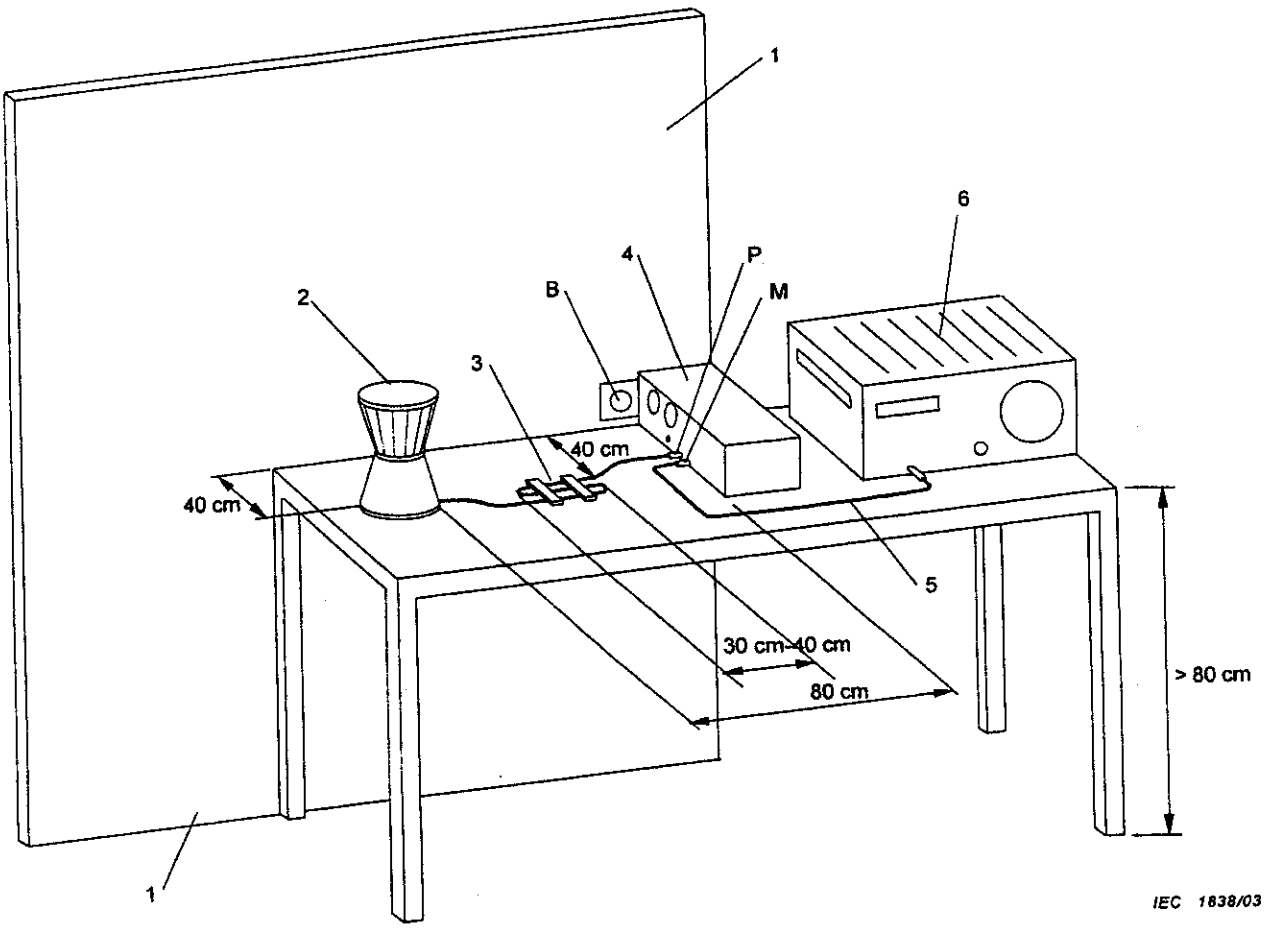
2.4.4.2 Procedure for the measurement of unsymmetric disturbance voltages with V-networks

2.4.4.2.1 Disposition of equipment with ground connection

For equipment under test which is required to be grounded during its operation, or the conductive housing of which can come into contact with ground, the unsymmetric radio interference voltage of the individual mains lead is measured with reference to the reference metal wall (general mass of the measuring equipment) to which the housing of the equipment under test is connected via its protective ground conductor and the ground connection of the artificial mains network (see the equivalent circuit in Figure 10).

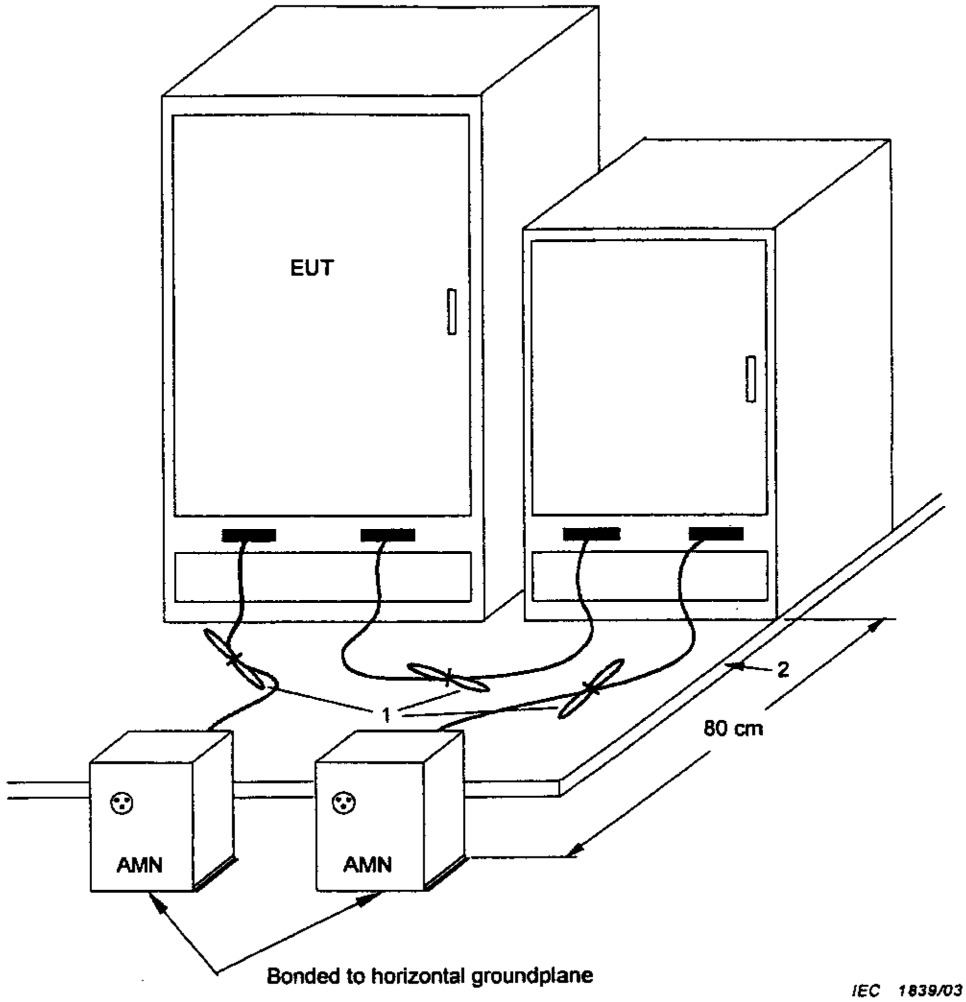
The parameters determining the interference potential of grounded test units are discussed in Clause A.3.

For EUTs with two or more power and safety conductors or special ground connections the measurement result depends much on the termination conditions of the mains terminals and the grounding conditions (refer also to 2.4.5 on measurement in systems).



1 Metallic wall 2 m × 2 m
2 EUT
3 Excess power cord (3 cm × 40 cm) (folded back and forth)
4 "V" mains network
5 Coaxial cable
6 Measuring receiver
B Reference ground connection
M Measuring receiver input
P Power to EUT

Figure 6 – Optional test configuration for an EUT with only a power cord attached
(see 2.4.4.1)



1 Excess cables shall be bundled in the centre or shortened to appropriate length.
2 The EUT and cables shall be insulated (up to 12 mm) from the ground plane.
3 The EUT is connected to one AMN. The AMN can be placed on top of or immediately beneath the ground plane.
All other equipment is powered from the second AMN.

Figure 7 – Test configuration: floor-standing equipment (see 2.4.4.1 and 2.4.5.2.2)

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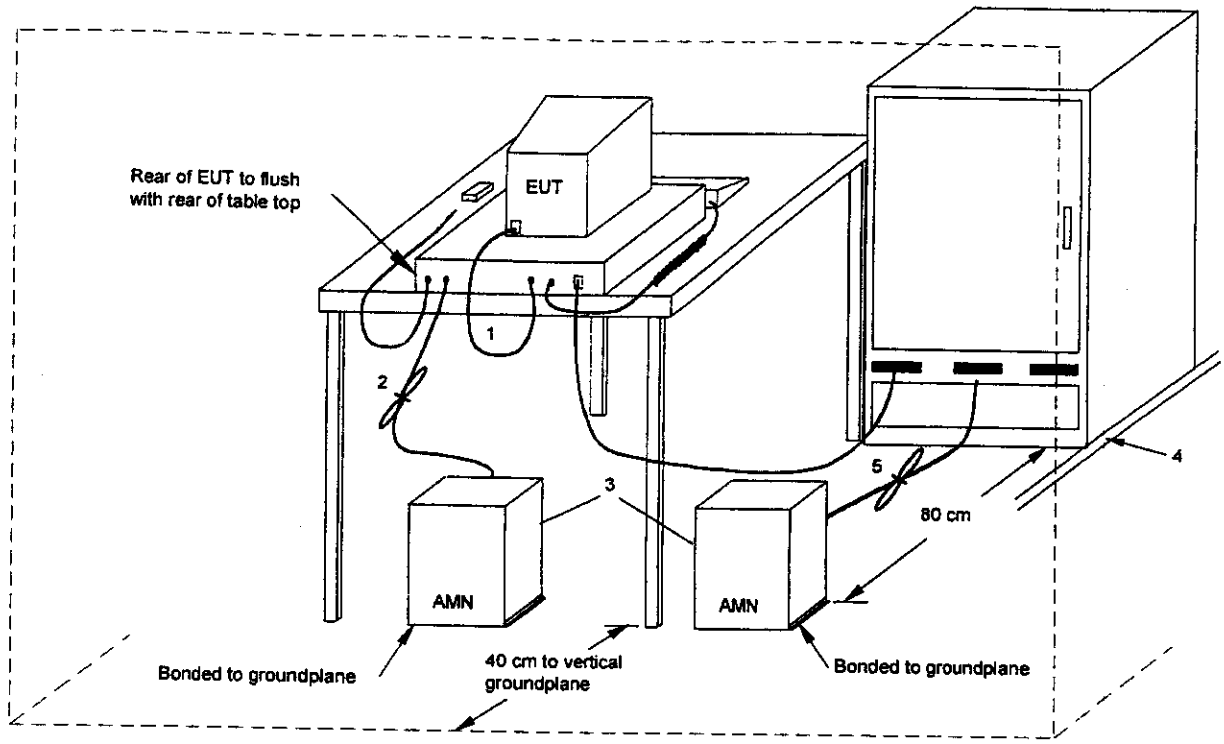


1 The interconnecting cables which hang closer than 40 cm to the ground plane shall be folded back and forth forming a bundle 30 cm – 40 cm long, hanging approximately in the middle between the ground plane and the table.

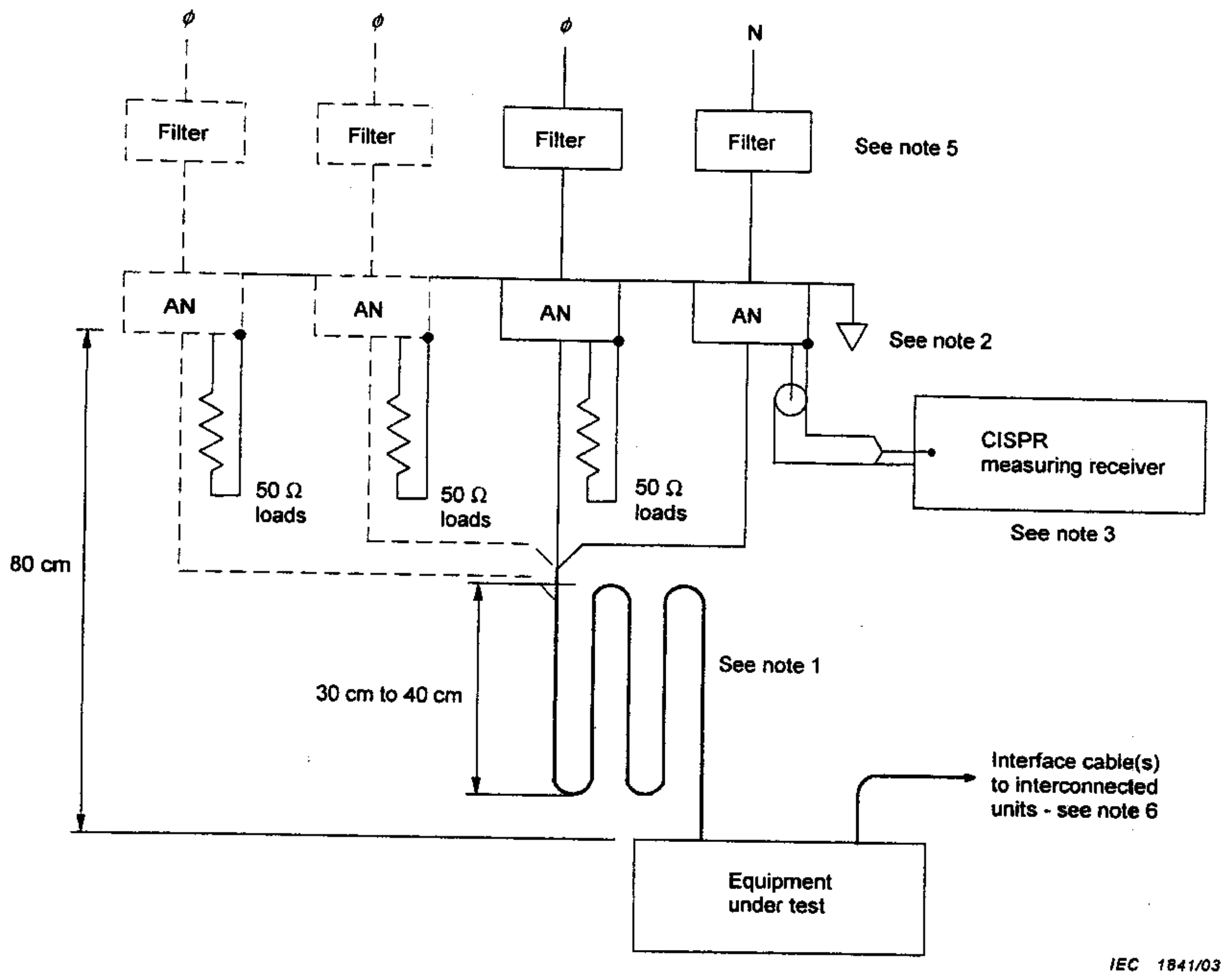
2 Excess power cords shall be bundled in the centre or shortened to appropriate length.

3 The EUT is connected to one AMN. The AMN may alternatively be connected to the vertical reference plane. All other equipment is powered from the second AMN.

4 The EUT and the cables shall be insulated (up to 12 mm) from the ground plane.

5 The I/O cable to the floor standing unit drapes to the ground plane and the excess is bundled. Cables not reaching the ground plane are dropped to the height of the connector or 40 cm, whichever is lower.

Figure 8 – Test configuration: floor-standing and table-top equipment
(see 2.4.4.1 and 2.4.5.2.2)



1 The length of the EUT power cord in excess of 80 cm shall be folded into a serpentine-like bundle and not coiled.

2 Connection of the AN to the ground plane shall provide a low impedance path at high frequencies. It shall be made using a solid flat metal conductor that has a length-to-width ratio of not more than 5 to 1.

3 The CISPR measuring the set shall only be grounded to the reference ground plane via the outer conductor of the coaxial cable.

4 Dotted lines represent the test set-up for the three-phase power.

5 Optional filter hook-up; replace with shorts if not used.

6 Interconnected units may be attached to a single AN via a power junction strip or box.

7 A table mounted or handheld EUT must be 40 cm from any grounded conducting surface of at least 2 m square and at least 80 cm from any other conductive objects, including devices that are part of the system or instrumentation.

Figure 9 – Schematic of conducted disturbance voltage test configuration
(see 2.4.4.1 and 2.4.5.2.2)

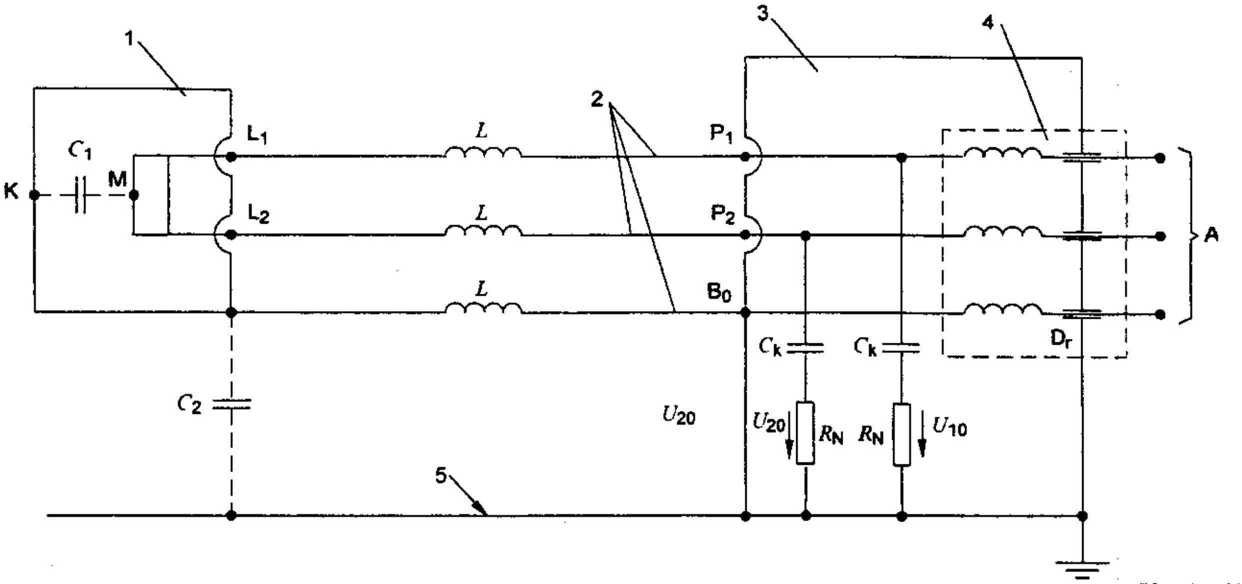


Figure 10a – Schematic for measurement and power circuit

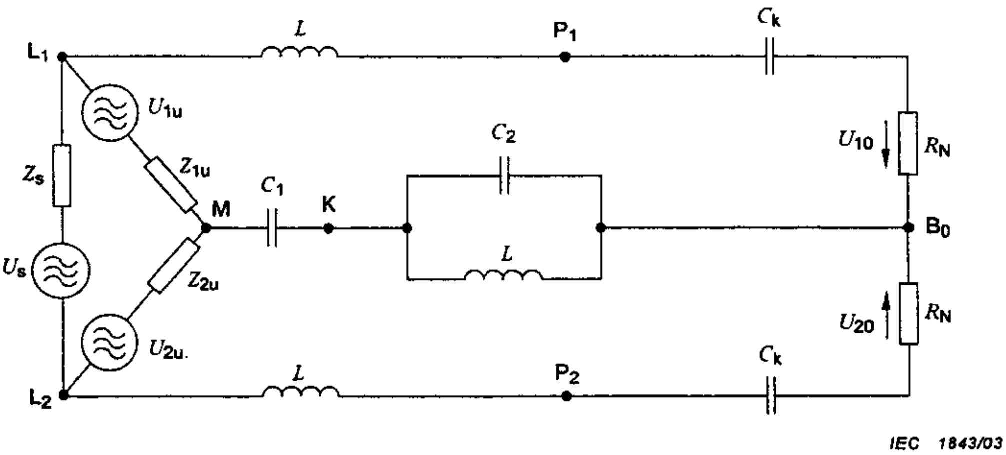


Figure 10b – Equivalent voltage source and measurement circuit

1	Equipment under test (EUT)
2	Power cord
3	"V" power mains network
4	Decoupling circuit (filter)
5	Metallic wall
A	Power input
B_0	Reference earth connection
L_1, L_2	Power cord connection (100 cm)
P_1, P_2	EUT plug to mains network
C_1	Stray capacitance within EUT to metallic parts
C_2	Stray capacitance of EUT to metallic wall (earth)
C_K	Coupling capacitors within mains network
D_r	Inductor (choke) for safety ground wire
K	Conductive structural parts of the EUT
L	Inductance of connecting wires
M	Fictitious mid-point of the internal common mode voltages
R_N	Simulation resistances (50 Ω or 150 Ω)
Z_s	Symmetric internal resistance of EUT
Z_{1u}, Z_{2u}	Common mode resistance of the EUT
U_{1u}, U_{2u}	Internal common mode voltage of the EUT
U_{10}, U_{20}	External measurable common mode voltage

Figure 10 – Equivalent circuit for measurement of common mode disturbance voltage for Class I (grounded) EUT (see 2.4.4.2.1)

As the ground safety conductors in the actual mains power supply installation may have a considerable length, and therefore do not guarantee a ground impedance as low and effective as in the standard test set-up with only a 1 m long ground wire connection to the reference mass, and moreover, since safety conductors need not be used on every product per IEC 60364-4, disturbance voltage measurements on pluggable Class I appliances shall be carried out according to 2.4.4.2.2, also without the safety or ground wire being connected (non-grounded measurement). If however for safety reasons it is necessary to maintain the safety function of ground wires, this can be achieved by the use of an RF choke or impedance equal to the network impedance of a V-network in the safety wire path.

Exceptions may be made for non-radiating or well screened EUTs which have to be grounded according to special requirements or instructions (see A 2.1 and A 4.1).

2.4.4.2.2 Disposition of equipment without ground connection

Devices without ground connection comprise electrical devices with protective insulation (protection Class II) and devices which can be operated without ground or safety conductor (device of protection Class III) and also pluggable protection Class I devices connected via an isolating transformer. For these devices, the unsymmetrical disturbance voltage of the individual conductors must be measured with respect to the metal reference ground of the measurement arrangement as shown in the equivalent circuit of Figure 11.

Since in the long and medium wave bands (0,15 MHz to 2 MHz) the results of measurement can be considerably influenced by the low series capacitance C_2 between the EUT and the reference ground, and since it is determined by the specified distance, the arrangement must be exactly followed and other external influence such as body and hand capacitance, for example, should be avoided.

2.4.4.2.3 Disposition of handheld equipment without a ground connection

Measurements shall first be made in accordance with 2.4.4.2.2. Additional measurements shall then be made using the artificial hand described in CISPR 16-1.

The general principle to be followed in the application of the artificial hand is shown in Figure 13. Terminal M of the RC element shall be connected to any exposed non-rotating metal work and to metal foil wrapped around all handles, both fixed and detachable, supplied with the EUT. Metalwork which is covered with paint or lacquer is considered as exposed metalwork and shall be directly connected to the RC element.

The artificial hand shall consist of metal foil wrapped around the case, or part thereof, as specified below. The foil shall be connected to one terminal (terminal M) of an RC element (see Figure 12) consisting of a capacitor of 220 pF ± 20 % in series with a resistor of 510 Ω ± 10 %; the other terminal of the RC element shall be connected to the reference earth of the measuring system.

The artificial hand is to be applied the following way:

a) when the case of the EUT is entirely of metal, no metal foil is needed, but the terminal M of the RC element shall be connected directly to the body of the EUT;
b) when the case of the EUT is of insulating material, metal foil shall be wrapped around the handle B (Figure 13), and also around the second handle D, if present. Metal foil 60 mm wide shall also be wrapped around the body C at that point where the iron core of the motor stator is located or around the gearbox if this gives a higher emission level. All these pieces of metal foil, and the ring or bushing A, if present, shall be connected together and to the terminal M of the RC element;

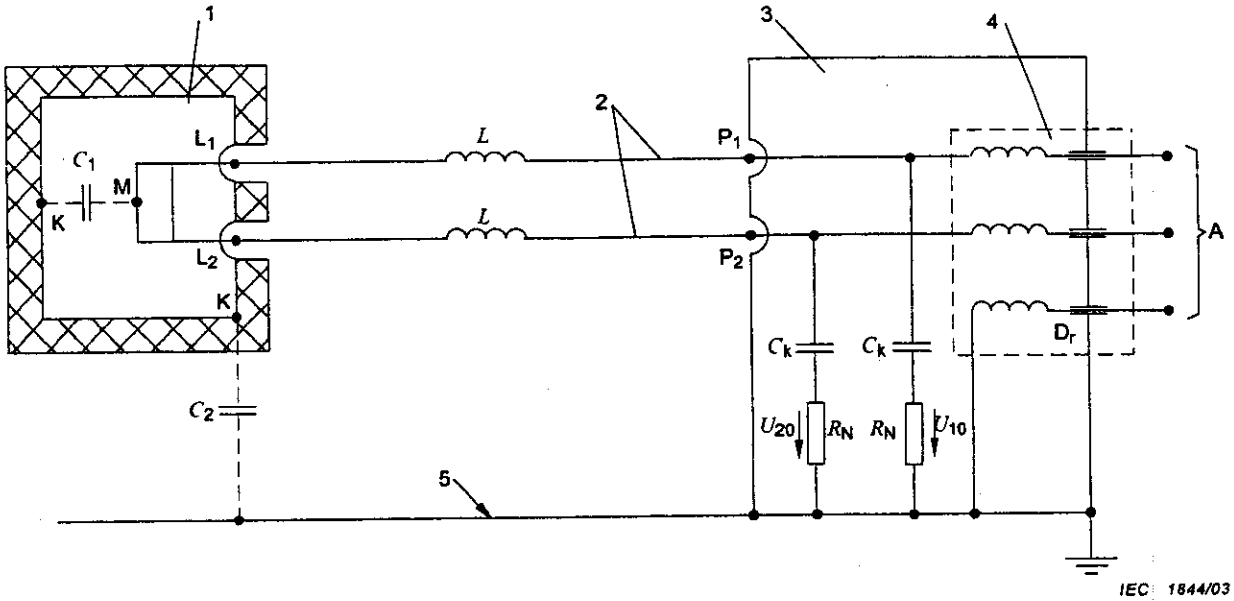


Figure 11a – Schematic for power and measurement circuit

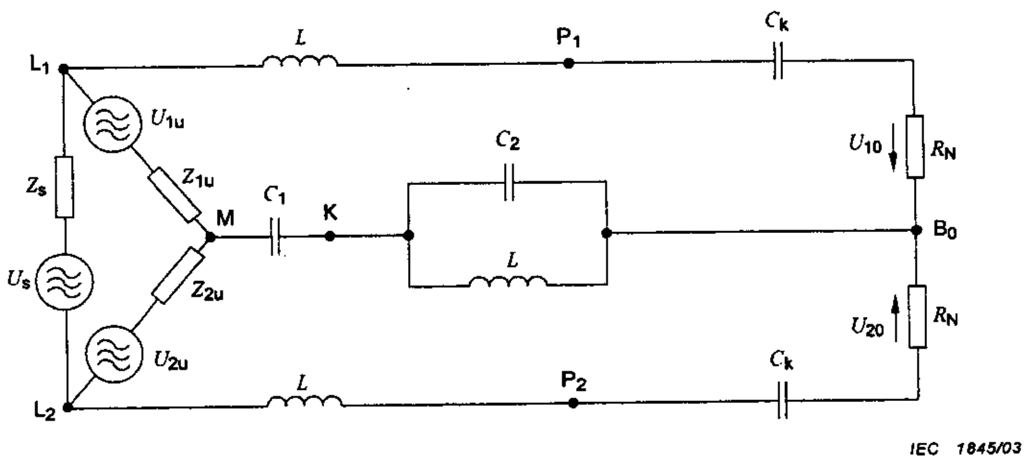
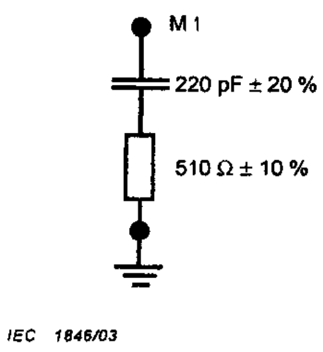


Figure 11b – Equivalent RFI source and measurement circuit

NOTE Refer to Figure 10 for symbols.

Figure 11 – Equivalent circuit for measurement of common mode disturbance voltage for Class II (grounded) EUT (see 2.4.4.2.2)



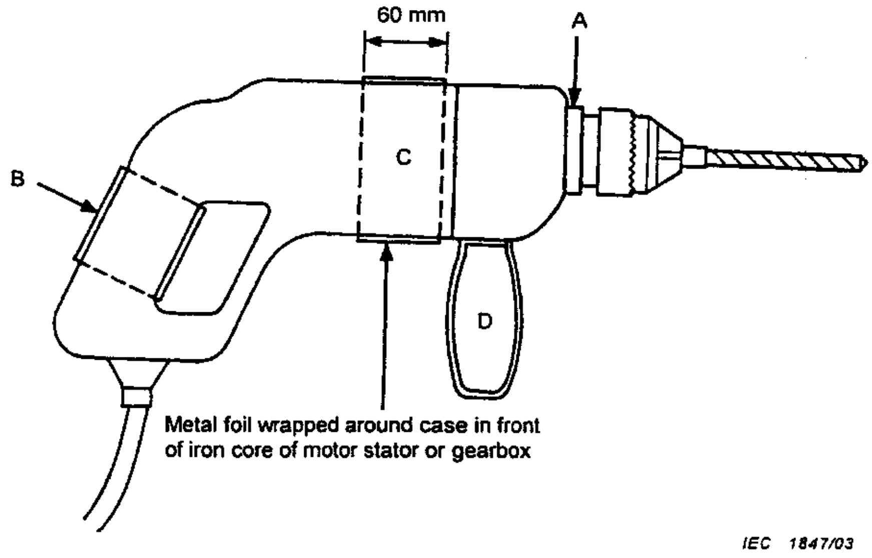


Figure 12 – RC element for artificial hand (see 2.4.4.2.3)

Figure 13 – Portable electric drill with artificial hand (see 2.4.4.2.3)

c) when the case of the EUT is partly metal and partly insulating material, and has insulating handles, metal foil shall be wrapped around the handles B and D (Figure 13). 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 that point where the iron core of the motor stator is located, or alternatively around the gearbox, if this is of insulating material and a higher emission level is obtained. The metal part of the body, the point A, the metal foil round 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 the EUT has two handles of insulating material A and B and a case of metal C, for example an electric saw (Figure 14), 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 the terminal M of the RC element.

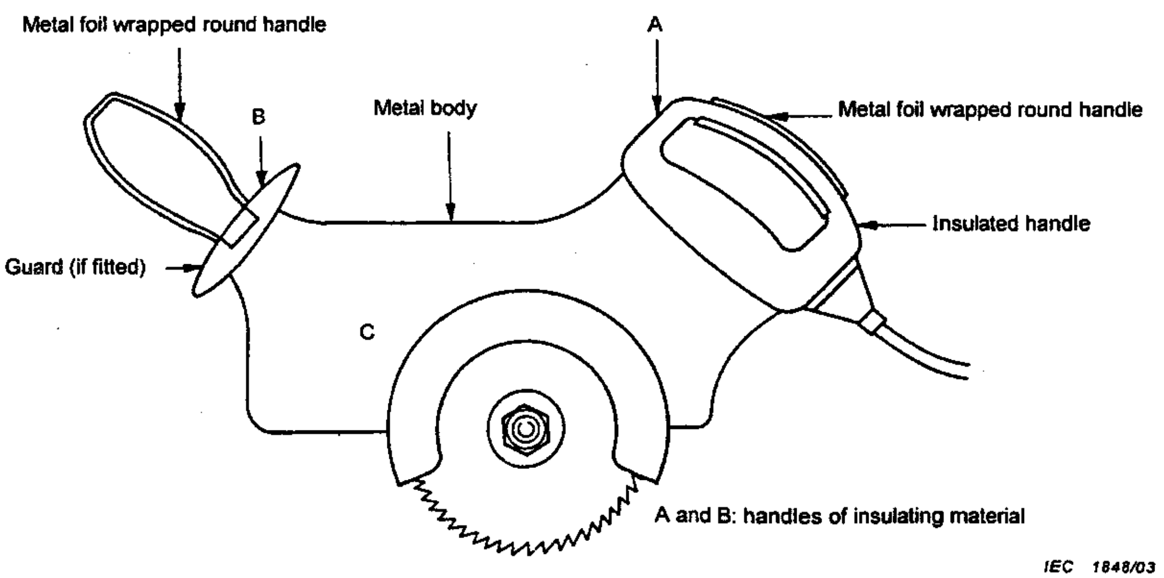


Figure 14 – Portable electric saw with artificial hand (see 2.4.4.2.3)

2.4.4.2.4 Disposition of keyboards, electrodes and other equipment sensitive to human touch

In the case of such equipment the artificial hand shall be applied as required by the product specifications and in general according to 2.4.4.2.3.

2.4.4.2.5 Disposition of equipment with external suppression components

If interference suppression devices are attached outside the EUT (e.g. in a plug device for connection to the mains) or as an element inserted in the connecting cable (power cord emission suppression device), or if shielded power cords are used, an additional 1 m long unshielded cable must be connected between the emission suppression device and the artificial network for measurement of the disturbance voltage. The line between the device and the emission suppression device must be placed in the direct proximity of the test object.

2.4.4.2.6 Disposition of equipment having auxiliary apparatus connected at the end of a lead other than the mains lead

NOTE 1 Regulating controls incorporating semiconductor devices are excluded from this subclause; the provisions of 2.4.4.4.1 shall apply.

NOTE 2 When the auxiliary apparatus is not essential to the operation of the EUT and has a separate test procedure specified elsewhere, this subclause does not apply. The main EUT is tested as an individual EUT.

NOTE 3 The ultimate decision whether to measure and apply limits is to be made in the relevant CISPR product publication.

Connecting leads exceeding 1 m in length shall be bundled in accordance with 2.4.4.1.

Measurements are not required when the connecting lead between EUT and auxiliary apparatus is permanently fixed on both ends and is either shorter than 2 m or shielded, provided that in the latter case the shielded lead is connected at both ends to the metal housing of the EUT and that of the auxiliary apparatus. Leads with removable plugs and sockets are considered to be extendable to a length of more than 2 m and measurements are required.

The equipment under test shall be arranged in accordance with previous parts of 2.4.4.2, with the following additional requirements:

a) the auxiliary apparatus shall be placed at the same height as and at the same distance from the grounded conducted surface and if the lead is long enough, it is to be treated in accordance with 2.4.4.1. If the auxiliary lead is shorter than 0,8 m, its length shall be maintained, and the auxiliary apparatus shall be placed as far away as possible from the main apparatus. When the auxiliary apparatus is a control, the arrangements for its operation must not affect the level of disturbance;
b) if an EUT having an auxiliary apparatus is grounded, no artificial hand shall be connected. If the EUT itself is made to be held in the hand, the artificial hand shall be connected to the EUT and not to any auxiliary apparatus;
c) if the EUT is not made to be held in the hand, auxiliary apparatus which is not grounded and is made to be held in the hand must be connected to the artificial hand. If the auxiliary apparatus is not made to be held in the hand either, it shall be placed in relation to a grounded conducting surface as described in 2.4.4.1.

In addition to the measurement on the terminals for the mains connection, measurements are conducted on all other terminals for incoming and outgoing leads (e.g. control and load lines) using a voltage probe connected to the input of the measuring receiver.

The auxiliary apparatus, control or load is connected to allow measurements to be made under all provided operating conditions and during interactions between the EUT and the auxiliary apparatus.

Measurements are performed both on the power input terminals of the EUT and the power input terminals of the auxiliary apparatus.

2.4.4.3 Measurement of common mode voltages at differential mode signal terminals

2.4.4.3.1 Measurement using the delta-type network

The common mode disturbance voltage at the terminals for differential mode signal lines of telecommunication, data processing and other equipment is measured with delta-networks in accordance with 5.1.6 of CISPR 16-1, in the frequency range 150 kHz to 30 MHz. The delta-networks specified in CISPR 16-1 could be amended in order to allow signal and d.c. current paths needed for the proper functioning of the EUT as long as the requirements on differential mode and common mode impedances of CISPR 16-1 are complied with.

When using the delta network for measurements on signal terminals, the differential mode rejection must be as great as needed not to give erroneous results when measuring a common mode disturbance voltage at the same frequency as the operational differential mode signal.

When the EUT is to be measured on its power supply terminals using an artificial mains network all voltage measurements shall be carried out with both networks connected simultaneously. The provisions prescribed in 2.4.4.1 and 2.4.4.2 are to be observed.

NOTE The frequency range of the delta-network can be extended to 9 kHz using the same network impedance if decoupling of the connected signal line and coupling to the measuring receiver are designed accordingly.

2.4.4.3.2 Measurements using the T-type network

Alternatively a common mode artificial network, e.g. a T-type network according to 5.10 of CISPR 16-1, can be used for the measurement of common mode disturbance voltages in the frequency range 9 kHz to 30 MHz.

In contrast to the delta-network which provides a differential mode and a common mode termination with equal simulation impedances of 150 Ω, the T-network provides only a common mode termination of 150 Ω and almost no loading and high isolation to the differential mode operational signal on the communication line.

At the supply side of the T-type network a signal simulator, load circuits for d.c. or the operational signal frequency of the EUT or other circuits needed for the operation of the EUT can be connected. These circuits shall either themselves provide a differential mode RF resistance of 100 Ω – 150 Ω, as required for the particular EUT, or with a termination to provide this resistance. When no external circuit is specified for the operation of the EUT a resistor of 150 Ω shall be connected as differential mode RF termination to the T-type network. Figure 15 shows an example of a T-type network.

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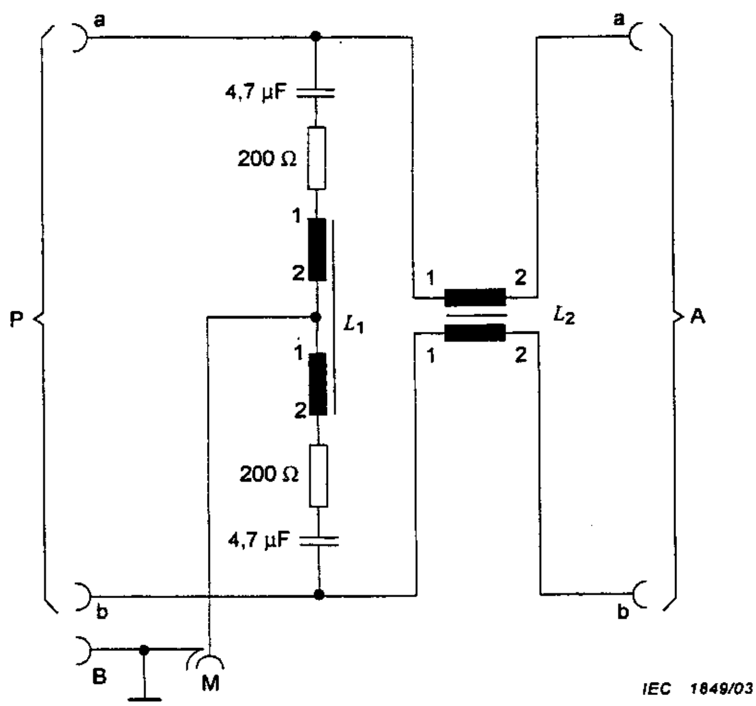


1 Beginning of winding
2 End of winding
A Terminals for telecommunication conductors
B Terminal for ground (metal wall)
M Terminal for measuring receiver (50 Ω)
P Connection to EUT
L_1 Differential mode inductance, 5 mH to 40 mH for each winding
L_2 Decoupling inductance (current compensated)

Figure 15 – Schematic diagram for simulation of telecommunication lines (T-1 network or telecom impedance simulation network) (see 2.4.4.3.2)

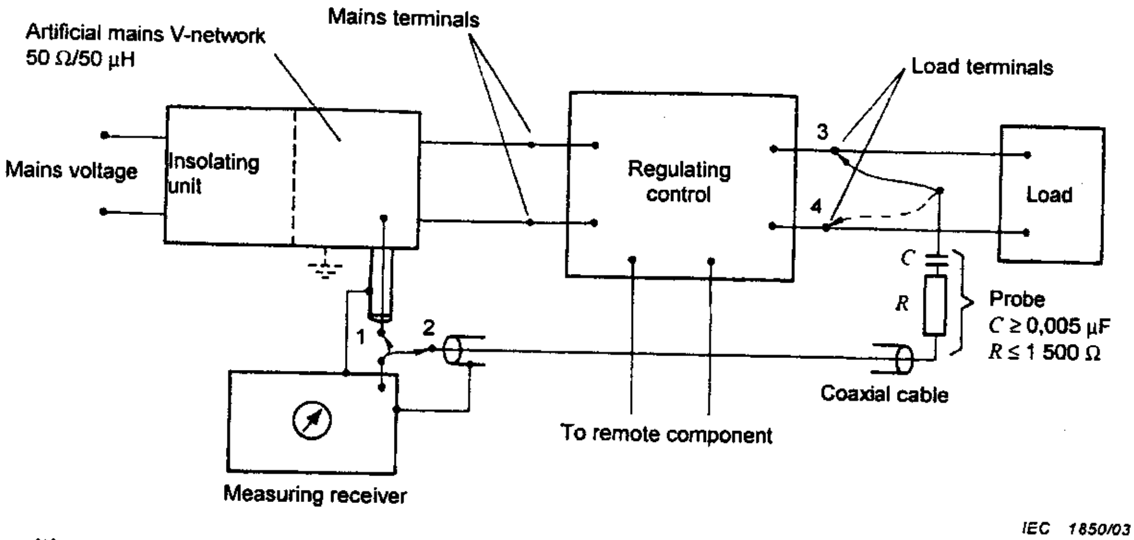
2.4.4.4 Measurements using voltage probes

2.4.4.4.1 With an artificial mains network

In order to test devices and systems with several connected or connectable lines, the disturbance voltage at the line connections, which cannot be measured with artificial mains networks (e.g. for connecting lines between parts of components which are separated from the mains) as well as the connecting jacks for antennas, control and load lines, must be measured with a voltage probe with a high input impedance (1 500 Ω or more) to ensure that the lines are not loaded by the probe.

For these cases, however, the primary power input wires must be isolated and RF terminated with the AMN. For the remaining lines, also those not to be measured with the probe, the corresponding conditions of 2.4.4.1 and the operating conditions laid down for the individual devices in the respective product specifications (e.g. CISPR 11 and CISPR 14-1) must be observed in regard to arrangement and length. The voltage probe is connected to the measuring receiver via a coaxial cable, the screen of which is connected to the ground reference and the case of the voltage probe. No connection shall be made directly from this case to live parts of the EUT.

Figure 16 shows an example for a test set-up for measuring the interference voltage of a semi-conductor regulating control.



Switch positions:

1 For mains measurements

2 For load measurements

3 and 4 Successive connections during load measurements

NOTE 1 The earth of the measuring receiver shall be connected to the artificial mains V-network.

NOTE 2 The length of the coaxial cable from the probe shall not exceed 2 m.

NOTE 3 When the switch is in position 2, the output of the artificial mains V-network at terminal 1 shall be terminated by an impedance equivalent to that of the CISPR.

NOTE 4 Where a two-terminal regulating control is inserted in one lead only of the supply, measurements shall be made by connecting the second supply lead as indicated in Figure 16a.

Figure 16 – Measuring example for voltage probes (see 2.4.4.4.1)

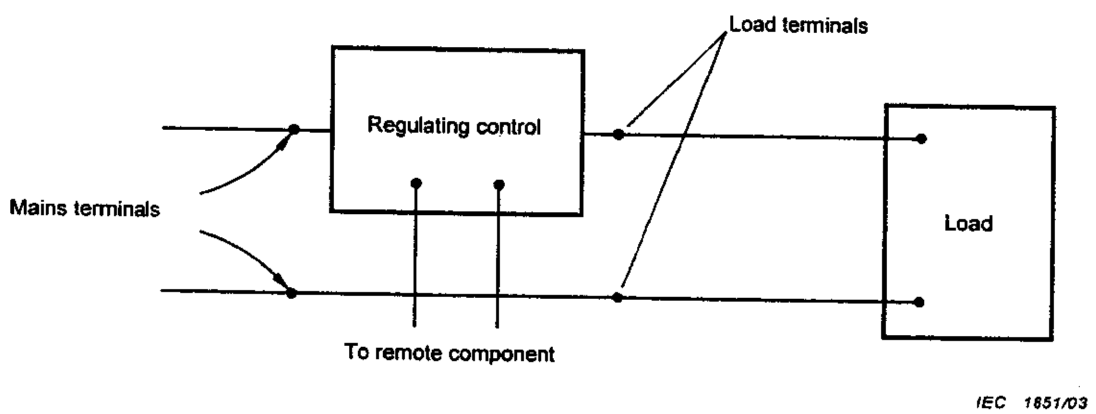


Figure 16a – Measurement arrangement for two-terminal regulating controls

2.4.4.4.2 Without an artificial mains network

During testing of EUTs which are not to be measured with artificial mains networks, the disturbance voltage is measured across a defined simulation resistance (e.g. artificial fence simulation in 7.3.7.2 of CISPR 14-1 or under open-circuit conditions with an exactly defined arrangement and line layout taking into consideration the specifications of 2.4.4.1). The disturbance voltage is measured with a high-impedance voltage probe.

This is valid also for e.g. power electronic devices which are fed from their own separate power supplies or battery devices to which separately installed lines are connected which are not to be loaded.

In the case of disturbance voltage measurements on separate individual power sources for currents of more than 25 A (e.g. battery, generator, convertor), an impedance measurement must be applied to ascertain that the tolerance of the simulated resistance, in accordance with CISPR 16-1 is not exceeded.

The flexible ground connection for probes with an input impedance Rx of more than 1 500 Ω should not be longer than 1/10 of the wave-length at the maximum measurement frequency and shall be connected in the shortest possible way to the metal surface serving as reference ground. In order to avoid additional capacitive loading of the test point by the screening of the probe, the tip of the probe should not exceed a length of approximately 3 cm. The screened connections to the measuring receiver must be arranged in such a way that the capacitance of the test object is not altered with respect to the reference ground.

2.4.4.4.3 Artificial mains network as voltage probe

Where the current rating of an EUT exceeds the rating of available AMNs, the AMN can be used as a voltage probe. The EUT port of the AMN is connected to each of the supply lines of the EUT (single or three-phase).

Prior to connecting an AMN to the mains supply, it must be safely connected to the local physical earth PE.

> **WARNING:** Before disconnecting the PE, the AMN should be disconnected from the mains supply. The mains port of the AMN is left open. When the AMN is connected as a voltage probe, the pins on the AMN power input connector/plug will be energized by the supply voltage. The pins on the plug must be made safe with an insulated protective cover or other means.

In the frequency range of 150 kHz to 30 MHz, the supply lines of the EUT shall be connected to the mains via an inductance of 30 µH to 50 µH (see Figure A.8, configuration 2). The inductance may be realized by a choke, a line of 50 m length or a transformer. In the frequency range of 9 kHz to 150 kHz a greater inductance will normally be required for decoupling from the mains. This guarantees also a reduction of noise from the mains network (see A.5).

Since measurements are preferable with AMNs in their standard configuration, the AMN as a voltage probe should only be used for *in situ* tests and where practical current limitations are exceeded. It shall not be used for testing according to a product standard unless it is referred to in the product standard as an alternative measuring method.

2.4.4.5 Measurements using current probes

Disturbance current measurements may be useful for several reasons. The first is that in some devices it may not be possible to insert an artificial mains network. This is particularly true when tests are performed on installed systems, or where the EUT has very high currents. A second reason for the use of the current probe is that at the lower end of the frequency range the mains impedance becomes very low, so the disturbance source is a current generator. The measurement of this current can be made by means of a current transformer without interrupting or disconnecting the mains connection.

Current probes shall conform to the requirements of 5.2 of CISPR 16-1.

Current probes enable the direct measurement of the D common mode components of the disturbance current by enclosing the cable containing all leads. Therefore, common mode disturbance currents can be easily separated from differential mode operating currents.

If measurements are performed with known load and source impedances, the disturbance voltage can be calculated.

If only one conductor is enclosed, the superposition of the differential and common mode disturbance current components is measured. If, in this case, any extremely high (above 200 A) operating current exists, there is a risk of false data because the magnetic core of the current probe may saturate.

2.4.5 System test configuration for conducted emissions measurements

2.4.5.1 General approach to system measurements

The general objective of defining a system test configuration for conducted emission measurements has the following key points:

- avoiding common mode disturbance ground loops;
- defining a configuration which is easily duplicated;
- decoupling of lines not being measured from the line being measured;
- placing of lines to achieve decoupling;
- duplicating requirements in 2.4.1 to 2.4.4 for the system test to the maximum extent possible.

Whenever possible, the disturbance voltage on a system line shall be measured with an AN. For currents up to 50 A, ANs can be used quite easily. The AN shall be installed within 80 cm of the system equipment being measured. Each wire of a multi-wire power mains circuit shall be routed through an AN. Each AN shall be terminated with a 50 Ω resistor at the measurement terminal.

The EUT shall be arranged and connected with cables terminated in accordance with the manufacturer's instructions.

For some measurements, relevant product publications may state a specific load to be used together with load voltage probes, instead of an AN. A voltage probe may also be used for conducted measurements when the mains current is above 50 A and an appropriate AN is not available. In this latter case test results with an AN will take precedence over the results with a voltage probe, however.

For some measurements, the use of current probes may be specified in the relevant product publication.

2.4.5.2 System configuration

The system shall be carefully configured, installed, arranged and operated in a manner that is most representative of the system as typically used (i.e. as specified in the instruction manual) or as specified herein. Equipment that typically operates within a system made up of multiple interconnected units should be tested as part of such a typical operational system.

Generally, the system that is tested shall be of the same type that is supplied to the end user. If the marketing information is not available or it is not practical to assemble extraordinary amounts of equipment to replicate a complete product installation, the test shall be performed using the best judgement of the test engineer in consultation with the design engineering staff.

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The results of any such discussion and decision process shall be documented in the test report.

The selection and placement of cables, a.c. line cords, host and peripherals depends on the type of EUT and must be representative of expected equipment installation. Three types are distinguished. First, there are systems normally used entirely on one table top. A second type of system consists of equipment normally used in a floor-standing configuration. These include systems mounted over a specially designed raised floor which facilitates intra-system connection under the raised floor. Equipment making up the floor-standing system can be interconnected with cabling lying on the floor, under the floor in a raised floor installation, or overhead according to normal installation. Third, there are systems that are a combination of floor-standing and table-top systems. The remainder of this clause provides instructions for the testing of each of these systems. In addition, the specific requirements in 2.4.1 to 2.4.4 shall be observed.

Equipment in a system, normally being floor-standing, shall be placed on a floor in accordance with 2.4.4.1. Equipment designed for both table-top and floor operation shall be tested only in the table-top configuration.

2.4.5.2.1 Operating conditions

The system shall be operated at the rated (nominal) operating voltage and typical load conditions – mechanical or electrical, or both – for which it is designed. Loads may be actual or simulated as described in the individual equipment requirements. For some systems, it may be necessary to develop a set of explicit requirements specifying the test conditions, operations, etc. to be used in testing a specific system.

If the system includes a visual display unit or monitor, the following operating conditions apply unless the product publication specifies otherwise:

a) set the contrast control to maximum;
b) set the brightness control to maximum or at raster extinction if raster extinction occurs at less than maximum brightness;
c) for colour monitors, use white letters on a black background to represent all colours;
d) select the worst case of positive or negative video if both are available;
e) set character size and number of characters per line so that the maximum number of characters per screen is displayed;
f) for a monitor that has no graphics capabilities, regardless of the video card used, a pattern consisting of random text shall be displayed;
g) for a monitor with graphics capabilities, even though another video card may be needed to accomplish a graphic display, a pattern consisting of a line of scrolling Hs should be displayed;
h) if a monitor has no text capabilities, use a typical display.

2.4.5.2.2 Interfacing equipments, simulators and cables

Compliance testing is performed with peripheral and cable placement which is judged realistic and likely to be found in the final installation. Figures 5, 7, 8 and 9 describe standardized test set-ups which will provide a basis for repeatability among testing laboratories and is consistent with the requirement for a realistic system and cable orientation. Any deviation from the standard test set-ups shall be documented together with its supporting rationale.

Since a system is required to interact functionally with other units, the actual interfacing units should be used. Simulators may be used to provide representative operating conditions, provided the effects of the simulator used in lieu of an actual interfacing unit properly represent the electrical, and in some cases the mechanical, characteristics of the interfacing units, especially concerning RF signals, impedances and shield terminations. Because of the added degree of uncertainty when a simulator is used, such use should be avoided if possible. In case of a dispute, measurements made with an actual interfacing unit shall take precedence. If a device is designed to be used only with a specific host computer or peripheral, it should be tested with that computer or peripheral.

Interfacing cables should be typical of normal use as supplied with the normal system and at least 2 m long unless the manufacturer's user manual specifies shorter cables. The same type of cable (that is, non-shielded, braided shield, foil shield, etc.) specified in the user manual should be used throughout the tests. Excessive lengths of cable shall be folded into a serpentine-like bundle at the approximate centre of the cable with the bundles 30 cm to 40 cm in length.

If shielded or special cables are used during the tests to achieve compliance, then a statement must be included in the test report and in the instruction manual advising of the need to use those types of cables.

Interface ports (connectors) shall have a cable connected to one of each type of functional interface port of the system, and each cable shall be terminated in a device typical of actual usage. Where there are multiple interface ports all of the same type, additional connecting cables shall be added to the system to determine the effect these cables have on emissions from the system.

Normally, the loading of similar ports is limited to the following:

a) availability of multiple loads (for large systems);
b) reasonableness of multiple loads representing a typical installation.

The rationale for the selection of the configuration and loading of ports shall be included in the test report; that is 25 % of possible cables were connected and the emissions did not increase by more than 2 dB when one or more cables were added. Additional ports on support units, interfacing units or simulators, other than those associated with the system or the minimum required system, need not be connected or used during testing.

2.4.5.2.3 Mains connection

If the system is an assembly of equipment each having its own power cords, the point of connection for the ANs is determined from the following rules:

a) each power cord which terminates in a mains supply plug of a standard design (IEC 60083, for example) shall be tested separately;
b) power cords or terminals which are not specified by the manufacturer to be connected via a host unit shall be tested separately;
c) power cords or field wiring terminals which are specified by the manufacturer to be connected to a host unit or other power-supplying equipment shall be connected to that host unit or other power-supplying equipment, and the terminals or cords of that host unit or other power-supplying equipment are connected to the ANs and tested;
d) where a special mains connection is specified, the necessary connection hardware to the AN shall be supplied by the manufacturer for the purpose of the test.

The ground safety conductor of units separately powered shall be isolated from the equipment under test by a 50 µH AN in the frequency range 0,15 MHz to 30 MHz. The normal AN mains input is connected to the reference ground in this use of the AN as a filter.

2.4.5.3 Measurements of interconnecting lines

In addition to the measurement on the terminals for the mains connection, measurements may need to be performed with a voltage probe on other terminals for incoming and outgoing leads (for example control and load lines). If the function of the equipment under test is affected by the 1 500 Ω impedance of the probe, the impedance at 50/60 Hz and at radio frequencies may need to be increased (for example 15 kΩ in series with 500 pF). In place of a voltage measurement, a current measurement with a current probe may also be used, if required (or offered as an option) in the product specification.

During the measurement, the ANs on the mains lead remain in place to provide a defined mains isolation and a defined RF termination. The auxiliary apparatus (control, load) is connected to allow measurements to be made under all provided operating conditions and during interactions between the equipments. Measurements are made on the specified terminals of each equipment.

If the connecting lines between equipments are permanently fixed on both ends and either shorter than 2 m or shielded, no measurements are necessary, provided that in the latter case the shielded cable is connected at both ends to the reference ground, that is metal housing of the equipments. Non-shielded connecting lines with plug(s) or socket(s) are considered to be extendable to a length of more than 2 m and therefore must be extended by at least 2 m and must be tested. Shielded cables must be at least 2 m long unless the user manual specifies shorter cables.

2.4.5.4 Decoupling of system components

One of the sources of inaccurate conducted measurements in a system is any ground circulating current. This ground current may be interrupted by installing a 50 µH AN in the frequency range 0,15 MHz – 30 MHz in the ground safety conductor to the EUT.

An additional source of circulating currents can be the shields of interconnecting cables between units. Therefore, the ground safety conductor to these units shall also be isolated by a 50 µH AN.

The measurement receiver should be referenced to ground only at the measurement point to prevent ground loops. (Caution: shock hazard may exist if the measuring set is not supplied with an isolation transformer.)

2.4.6 *In situ* measurements

Testing may be performed at the end user's or manufacturer's premises, if the system cannot be set up on test site. In this case, both the system and its location are considered as the system tested. The emission results are unique to the installation site because site containment properties affect the measurement. However, where testing of a given system has been accomplished at three or more representative locations, the results may be considered representative of all sites with similar systems for purposes of determining compliance with emission requirements (if allowed in the procuring or requirement document.)

The disturbance voltage shall be measured under the existing conduction conditions with non-reactive pick-up devices (high resistance voltage probes). The conduction conditions and measurement results are affected by:

- the existing reference ground or the reference mass used during measurement. Neither a conducting ground plane nor an AN shall be installed for user's installation testing unless one or both are to be a permanent part of the installation;
- the RF characteristics and loading conditions for the power mains conduction;
- the ambient RF environment; and
- the input impedance of the pick-up device.

2.4.6.1 Reference ground

The existing ground at the place of installation should be used as reference ground. This should be selected by taking high-frequency (RF) criteria into consideration. Generally, this is accomplished by connecting the EUT via wide straps, with a length-to-width ratio not exceeding 3, to structural conductive parts of buildings that are connected to earth ground. These include metallic water pipes, central heating pipes, lightning wires to earth ground, concrete reinforcing steel and steel beams.

In general, the safety and neutral conductors of the power installation are not suitable as reference ground as these may carry extraneous disturbance voltages and can have undefined RF impedances.

If no suitable reference ground is available in the surroundings of the test object or at the place of measurement, sufficiently large conductive structures such as metal foils, metal sheets or wire meshes set up in the proximity can be used as reference ground for measurement.

The general requirements of 2.4.4.2.1 and of Annex A should be observed.

2.4.6.2 Measurement with voltage probes

Testing of conducted disturbance voltage is made with the voltage probe. Special precautions must be taken to establish a reference ground for the measurements.

Any voltage decrease caused by loading of the circuit to be measured can be determined qualitatively by varying the voltage probe input impedance. If the input impedance of the voltage probe is high compared to the internal impedance of the test point or of the tested network, then only slight differences in the measurement of the disturbance voltage occur when the probe input impedance is increased. The input impedance of the probe can be doubled by series connection of a 1 500 Ω resistor. If the disturbance voltage is reduced by (the predicted) 5 dB or 6 dB, then the 1 500 Ω probe can be used to measure the disturbance voltage.

2.4.6.3 Selection of measuring points

Radio disturbance voltage measurements at the place of installation are carried out at the boundaries of the user's premises, of industrial areas, or at points to be specified within the influence area of receiving system.

2.4.6.3.1 Measurements on mains and other supply leads

In power supply networks it is sufficient to measure the unsymmetric disturbance voltage with the voltage probe at accessible power outlets near the power entrance to the building.

2.4.6.3.2 Measurements on unshielded and shielded cables

In the case of non-shielded and shielded signal, control and load leads with non-grounded shield leaving the boundaries, the unsymmetric disturbance voltage shall be measured with the voltage probe on the individual wires or the screens against reference ground.

In the case of shielded cables with grounded shield, the common mode disturbance current is measured at a distance greater than one-tenth wavelength from the connecting and grounding points using a current probe.

2.5 Measurements using the absorbing clamp, 30 MHz to 1 000 MHz

2.5.1 General

Absorbing clamps (see Figure 13) are suitable for the measurement of the disturbance power that can be radiated from a cable for some types of equipment depending on construction and size. The precise measuring procedure and its applicability is to be specified in each product specification. If the dimensions of the EUT, without connecting leads, approach a quarter of a wavelength of the measuring frequency, direct cabinet radiation may occur and the absorbing clamp method is not suitable to assess the full radiation capacity of the EUT. In general, the method is most useful for small EUTs and in the frequency range of 30 MHz to 300 MHz.

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

Equipment having external leads other than a mains lead can radiate disturbance from such leads, shielded or unshielded, in the same manner as radiation from the mains lead. Absorbing clamp measurements can also be used on these leads for diagnostic purposes.

Radiation from leads at frequencies above 300 MHz, up to 1 000 MHz, may be measured with a suitable absorbing clamp. Such measurements are also suitable for diagnostics. However, it should be noted that radiation could emanate directly from the equipment as well.

Historical background of the absorbing clamp is contained in Annex C.

2.5.2 Measurements

When using the absorbing clamp, the EUT is placed on a non-metallic table at least 80 cm high. The lead to be measured is stretched horizontally in a straight line, to permit variation in position of the absorbing clamp along the lead to find the maximum indication. The lead shall be at least a half-wavelength at the lowest frequency of measurement, plus the length of the absorbing clamp and a possible second absorbing clamp: at 30 MHz the lead length is 6 m and with the second (filtering) absorbing clamp must be at least 7 m. Leads shorter than 1 m are not suitable for absorbing clamp measurements.

The absorbing clamp is placed around the lead to be measured as shown in Figure 17. The position of the absorbing clamp along the lead shall be varied from zero to one half-wavelength distance from the EUT at each test frequency. The maximum indication obtained on the measurement receiver connected to the absorbing clamp is proportional to the disturbance power available.

When measurements are made on an EUT having more than one lead attached, detachable leads shall be removed if operationally possible, at the time when another lead is measured. A lead which cannot be removed shall be isolated by means of lossy ferrite rings or another absorbing clamp put around the lead immediately adjacent to the EUT.

The test arrangement for the absorbing clamp is shown in Figure 17. No person or metallic objects shall be positioned within 80 cm of the measuring set-up. The required movement of the absorbing clamp may be performed with pulleys and a rope that is operated by a motor that can be operated from a remote location.

The power corresponding to the measured receiver voltage indication at each test frequency is derived from the absorbing clamp calibration procedure described in 5.3 of CISPR 16-1.

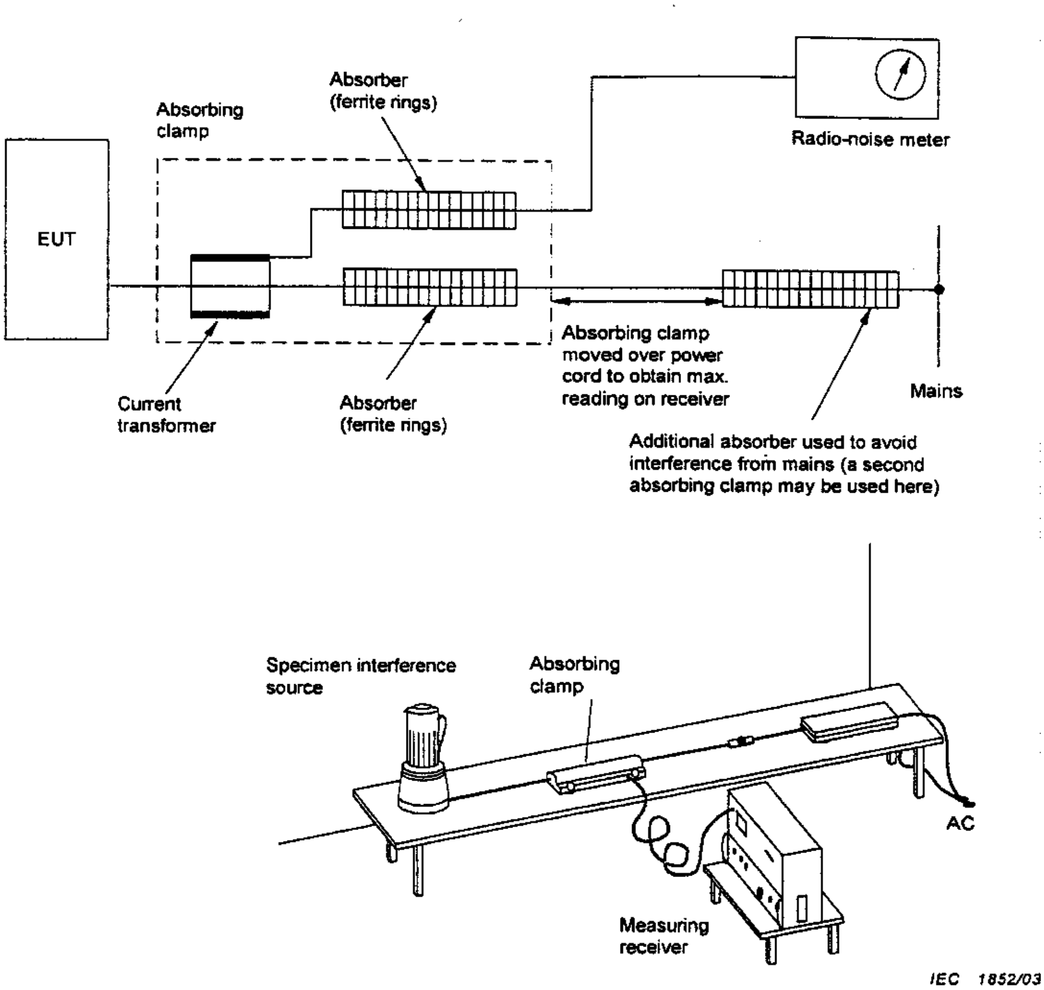


Figure 17 – Test configuration for absorbing clamp (see 2.5.2)

2.6 Measurement of radiated disturbances

2.6.1 Introduction

This section sets forth the general procedures for the measurement of the field strength of radio disturbance produced by devices and systems. Experience with radiated disturbance measurements is less extensive than that of voltage measurements. The radiated disturbance measurement procedures are therefore open to revision and extension as knowledge and experience are accumulated. In particular, attention shall be given to the effect of leads and cables associated with the EUT.

For some products, it may be required to measure the electric, the magnetic, or both components of the radiated disturbance. Sometimes a measurement of a quantity related to radiated power is more appropriate. Normally measurements should be made of both the horizontal and vertical components of the disturbance with respect to the reference ground plane. The results of measurements of either the electric or magnetic components may be expressed in peak, quasi-peak, average or r.m.s. values.

The magnetic component of the disturbance is normally measured at frequencies up to 30 MHz. In magnetic field measurements only the horizontal component of the field at the position of the receiving antenna is measured when using the distant antenna procedure. If the large loop antenna (LLA) system is used, the three orthogonal magnetic dipole moments of the EUT are measured. (Note that in the single antenna method, the horizontal component of the field at the position of the antenna is determined by the horizontal and vertical dipole moments of the EUT, because reflection plays a part.)

2.6.2 Field-strength measurements in the frequency range 9 kHz to 1 GHz

Field-strength measurements may be made on an open area test site, in an absorber-lined shielded enclosure, in a reverberating chamber or using a LLA system. For practical reasons other test sites may have to be specified.

2.6.2.1 Open area test site measurements

The open area test site shall conform with the relevant specifications in 5.6 of CISPR 16-1 for its physical and electrical properties and for its validation.

2.6.2.2 General measurement method

Figure 18 shows the concept of measurements made on an open area test site with the direct and ground reflected rays arriving at the receiving antenna.

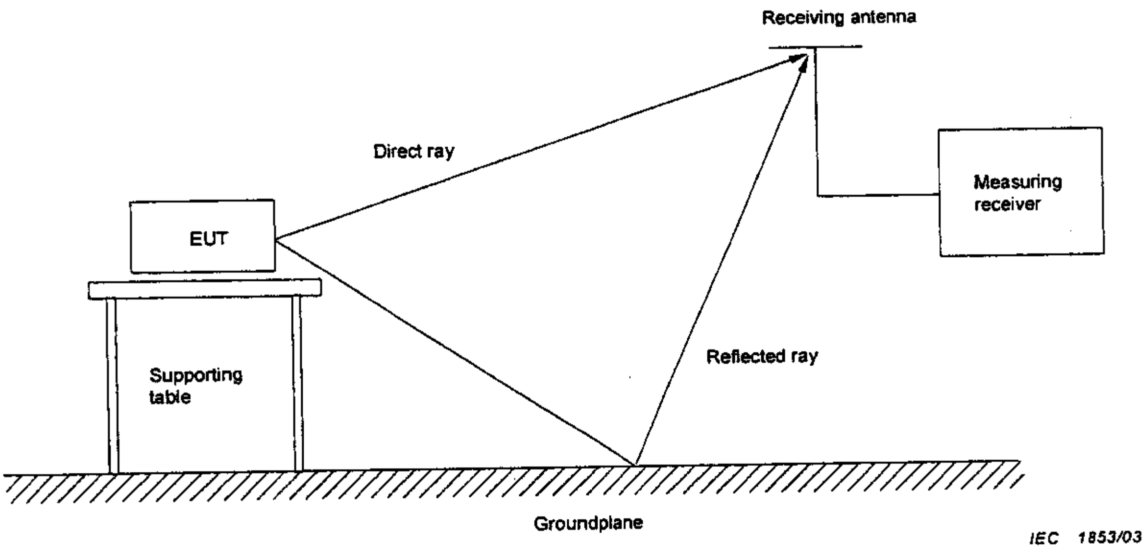


Figure 18 – Concept of electric field strength measurements made on an open area test site with the direct and reflective rays arriving at the receiving antenna
(see 2.6.2.2)

The EUT is set up at a specified height above the ground plane and configured to represent normal operating conditions. The antenna is positioned at the specified separation distance. The EUT is rotated in the horizontal plane and the maximum reading noted. The height of the antenna is adjusted so that the direct and reflected rays approach or meet in-phase addition. The procedural steps may be interchanged and may need to be repeated to find the maximum disturbance. For practical reasons the height variation is restricted and hence perfect in-phase addition may not be achieved.

2.6.2.3 Measurement distance

An EUT subject to a radiated disturbance limit at a specified distance should be measured at that distance unless to do so would be impractical because of equipment size, etc. The measurement distance is the length of the projection of the EDTs closest point to the antenna and the midpoint of the antenna onto the ground plane. In some test set-ups the distance is measured from the antenna to the radiation centre of the EUT. For a measurement distance of 10 m either method may be used. A distance of 10 m is preferred at most outdoor sites since at this distance the expected level of the disturbance being measured is sufficiently above the general ambient noise level to permit useful testing. Distances of less than 3 m or greater than 30 m are not generally used. If a measurement distance other than the specified distance is necessary, the results should be extrapolated using the procedures specified in the product standards. If no guidance is given, suitable justification for extrapolation shall be provided. In general, extrapolation does not follow a simple inverse distance law.

Where possible, measurement should be made in the far field. The far field region may be defined by the following conditions.

Measurement distance d is selected so that:

a) $d \geq \lambda/6$. At this distance $E/H = Z_0 = 120\ \pi = 377\ \Omega$, that is electrical and magnetic field strength components are perpendicular to each other, and the measurement error is in the order of 3 dB if the EUT is regarded as being a tuned dipole antenna; or

b) $d \geq \lambda$, condition for a plane wave, where the error is in the order of 0,5 dB if the EUT is regarded as a tuned dipole antenna; or

c) $d \geq 2D^2/\lambda$, where D is the largest dimension of either the EUT or the antenna determining the minimum aperture for the illumination of the EUT, which applies to cases, where $D >> \lambda$.

2.6.2.4 Antenna height variation

For electric field-strength measurements the antenna height above the ground plane shall be varied within a specified range to obtain the maximum reading which will occur when the direct and reflected rays are in phase. As a general rule, for measurement distances up to and including 10 m, the antenna height for electric field strength measurements shall be varied between 1 m and 4 m. At greater distances of up to 30 m, preferably the height shall be varied between 2 m and 6 m. It may be necessary to adjust the minimum antenna height above ground down to 1 m in order to maximize the reading. These height scans apply for both horizontal and vertical polarization, except that for vertical polarization, the minimum height shall be increased so that the lowest point of the antenna clears the site ground surface by at least 25 cm. For magnetic field strength measurements using the single magnetic loop antenna, the height of the receiving antenna may be fixed at a specified elevation (typically 1 m from ground to the bottom of the loop antenna). The loop antenna and EUT shall be rotated in azimuth to maximize the measured disturbance.

2.6.2.5 Product specification details

In addition to specifying the detailed measurement method and the disturbance parameters to be measured, the product standards shall include other relevant details as outlined below.

2.6.2.5.1 Test environment

The influence of the test environment shall be considered so as to ensure correct functioning of the EUT. Important parameters in the physical environment shall be specified, e.g. temperature and humidity.

The electromagnetic environment needs special consideration to ensure accurate disturbance measurements. The ambient radio noise and signal levels measured at the test site with the EUT de-energized should be at least 6 dB below the limit. It is recognized that this is not always realizable at all frequencies. However, in the event that the measured levels of the ambient plus EUT radio noise emissions are not above the limit, the EUT shall be considered to be in compliance with the limit. For further guidance on ambient levels and resulting measurement error, see 2.3.1.1 and Annex E.

If the ambient field-strength level at frequencies within the specified measurement ranges exceeds the limit(s), the following alternatives may be used:

a) perform measurements at a closer distance and extrapolate results to the distance at which the limit is specified. The extrapolation formula shall be as recommended by the product standard or shall be verified by measurements at no less than three different distances;

b) perform measurements in critical frequency bands during hours when broadcast stations are off the air and ambients from industrial equipment are lower;

c) compare the amplitude of the EUT disturbance at the frequency under investigation with the amplitude of disturbance on adjacent frequencies in a shielded room or anechoically treated shielded room. The amplitude of the EUT disturbance at the frequency under investigation can be estimated by measuring the amplitude of the adjacent frequency disturbance and making a comparison;

NOTE The shielded or anechoic room should not be used for compliance determination at the other EUT frequencies unless the anechoic room data is correlatable to the open area test site data.

d) in orienting the axis of an open field area test site, it is desirable to consider the directions of strong ambient signals, so that the orientation of the receiving antenna on the site discriminates against such signals as far as possible;

e) for narrowband disturbances from the EUT occurring near an RF ambient, when both are within the standard bandwidth, a narrower instrument bandwidth may be useful.

2.6.2.5.2 Configuration of equipment under test

The operating conditions of the EUT shall be specified, e.g., the characteristics of the input signals, the modes of operation, the arrangement of components, the lengths and types of interconnecting cables, etc.

The testing of individual and multi-component systems shall satisfy the following two conditions:

a) the system is configured for use in a typical manner.

b) the system is configured in a manner that will maximize disturbances.

The term "system" refers to the EUT in combination with the components that are connected to the EUT and all required connecting cables.

The term "configuration" refers to the orientation of the EUT, the other components of the system, the interconnecting cables, and the power mains leads that comprise the system. During all measurements, the configuration of the system shall be adjusted so that the above two conditions, the condition a) being satisfied first and followed by condition b), are fulfilled, within the guidelines described in the following paragraphs.

The term "typical" is used to describe the arrangement of how the EUT will actually be used. Guidelines for setting up a typical configuration are outlined below.

For equipment designed to be part of a multi-unit system, the EUT shall be installed in a typical system and configured in accordance with the manufacturer's instructions. It shall also be operated in a manner that is representative of the typical usage for that EUT. During all tests, the EUT and all system components shall be manipulated within the confines of typical usage to maximize each disturbance.

Interface cables shall be connected to each interface port on the EUT. The effect of varying the position of each cable shall be investigated to find the configuration that maximizes each disturbance as constrained by its typical configuration in actual use. The number of manipulations may be limited if a few such cable configurations will lead to maximum disturbances over the frequency range investigated.

Interface cables shall be of the type and length specified by the equipment manufacturer.

Any excess length of each cable shall be separately bundled in a serpentine fashion at the approximate centre of the cable with the bundle 30 cm to 40 cm in length. If it is impractical to do so because of cable bulk or stiffness or because the testing is being done at a user installation, disposition of the excess cable length is left to the discretion of the test engineer and should be noted in the test report. Different requirements for excess cabling may be specified in the product standard.

Cables shall not be placed underneath or on top of the EUT or on system components unless it is appropriate to do so, e.g. a cable is normally routed through overhead cable racks or under the ground plane. Cables shall be positioned adjacent to the exterior cabinets of the EUT and all system components only if typically used in that manner. The EUT should be investigated in different modes of operation.

For an EUT normally operated on top of a table, radiated emission tests should be performed with the EUT on a non-conducting table, the top of which is of suitable size. The table should be placed on a remotely controlled rotating platform constructed with non-conducting materials. The top of the rotating platform should normally be less than 0,5 m above the ground plane and the height of the table and platform together 0,8 m above the ground plane. If the rotating platform is at the same elevation as the ground plane, its surface shall be of conducting material and the 0,8 m height shall be measured with respect to the top of the rotating platform. An EUT normally placed on the floor will be tested on the floor. A flush-mounted rotating platform is useful in this situation.

The EUT shall be grounded in accordance with the manufacturer's requirements and conditions of intended use. If the EUT is operated without a ground connection, it shall be tested ungrounded. When the EUT is furnished with a grounding terminal or internally grounded lead which is to be connected in actual installation conditions, the ground lead or connection shall be connected to a ground plane (or facility for earth ground), simulating actual installation conditions. Any internally grounded lead included in the plug end of the a.c. mains cord of the EUT shall be connected to ground through the mains power service.

2.6.2.6 Measurement instrumentation

The measurement instrumentation, including antennas, shall conform with the relevant requirements in CISPR 16-1.

2.6.2.7 Field-strength measurements on other out-door sites

Out-door test sites similar to an open area test site but without any metal ground plane may have to be prescribed for practical reasons for some products, e.g. ISM equipment and motor vehicles. The provisions given in 2.6.2.3 to 2.6.2.6 are valid. Equally, the general provisions given in 5.6 of CISPR 16-1 are referred to but not the requirements on validation.

2.6.2.8 Measurements in reverberating chambers

(Under consideration)

2.6.2.9 Measurement in absorber-lined shielded enclosures

2.6.2.9.1 Measurement in absorber-lined shielded enclosures with groundplane (Semi-Anechoic Chambers = SAC or Semi-Anechoic Room = SAR)

Under consideration.

2.6.2.9.2 Measurement in fully absorber-lined shielded enclosures (Fully Anechoic Chamber = FAC or Fully Anechoic Room = FAR)

2.6.2.9.2.1 Test set-up

The same type of antenna shall be used for EUT emission testing as the receive antenna used for the FAR validation testing. The antenna height is fixed at the geometrical middle height of the test volume. Measurement will be done in horizontal and vertical polarisation of the receive antenna. Emissions should be measured while the turntable positions the EUT in each of at least three successive azimuth positions (0°, 45°, 90°), when continuous rotation is not required.

The test distance is measured from the reference point of the antenna to the boundary of the EUT. In the case of a difference between the reference point on an antenna and the phase centre, a correction factor may be applied to obtain the field strength at the test distance.

NOTE The correction factor, C_{Rd} [dB], equation (4a), may be added to the measured field strength value in order to reduce its uncertainty. In the calibration procedure of the antenna a phase correction factor C_{Rd} will be measured for each frequency. (The procedure will be defined with antenna calibration or calculated from the mechanical spacing of the log.-periodic elements) together with the Antenna Factor (AF). The two factors (C_{Rd}, and AF) will be added in dB to the voltage at the output of the antenna to get the field strength equation (4b). If a phase centre correction is not included, an additional term must be included in the uncertainty budget (see 2.6.2.9.2.4).

$$C_{Rd} = 20 \lg [(R + P_f - d)/R] \quad (4a)$$

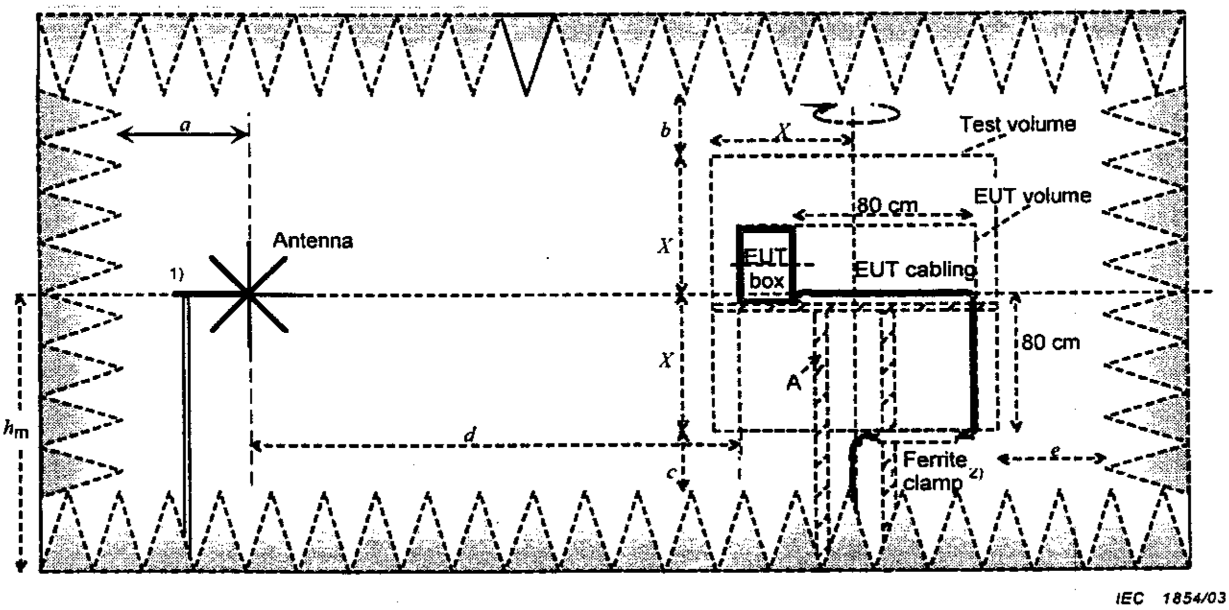
E-field strength is given by equation (4b):

$$E_f = V_f + AF_{FS(f)} + C_{Rd} \quad (4b)$$

where

f = frequency, (MHz)
R = the required separation distance from the source to the reference point on the antenna (m).
P_f = phase centre position as a function of frequency, (m from tip of antenna)
d = distance of the reference point on the antenna from the antenna tip (m).
E_f = E-field at distance d from source; expressed in dB (µV/m).
V_f = voltage at output of antenna at frequency f; expressed in dB (µV).
C_{Rd} = phase centre correction factor; expressed in dB
$AF_{FS(f)}$ = antenna factor (free space) for E-field at the phase centre; expressed in dB (m^{-1}).

Figure 19 illustrates a typical test set-up.



A = turntable and EUT-support

$2X$ = 1,5 m; 2,5 m; 5 m, i.e. corresponds to test distance used (3 m, 5 m, or 10 m respectively)

h_m = middle level of the test volume

a, b, c and e ≥ 0,5 m recommended (≥ 1 m is more convenient), the actual value will be consistent with the FAR calibration procedure of a future version of CISPR 16-1.

d = 3 m; 5 m or 10 m

1) The antenna and cable lay-out shall be validated together and used in the same configuration during EUT-test.

2) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 19 – Typical test set-up in FAR, where a, b, c and e depend on the room performance

The EUT shall be placed on a turntable. Figures 19, 20 and 21 explain the different dimensions within the FAR. The turntable, antenna mast and supporting floor shall be in place during the validation procedure, and consist largely of material transparent to electromagnetic waves. The distances a, b, c and e may be limited by the size of the test volume to be specified in 5.6.8.2.2

of the future version of CISPR 16-1[1]. The level of the bottom plane (absorber height plus *c*) will be the level for floor standing equipment (transport pallet height will be outside the test volume).

2.6.2.9.2.2 EUT position

The EUT shall be configured, installed, arranged and operated in a manner consistent with typical applications. Interface cables shall be connected to each type of interface port of the EUT.

If the EUT consists of separate devices, the space between the devices shall be in normal configuration but with 10 cm separation if possible. Interconnecting cables shall be bundled. The bundle shall be around 30 cm to 40 cm long and longitudinal to the cable.

Ancillary equipment, which is required to exercise the EUT but does not form part of the EUT, shall be located outside the screened room.

The entire EUT shall fit in the test volume.

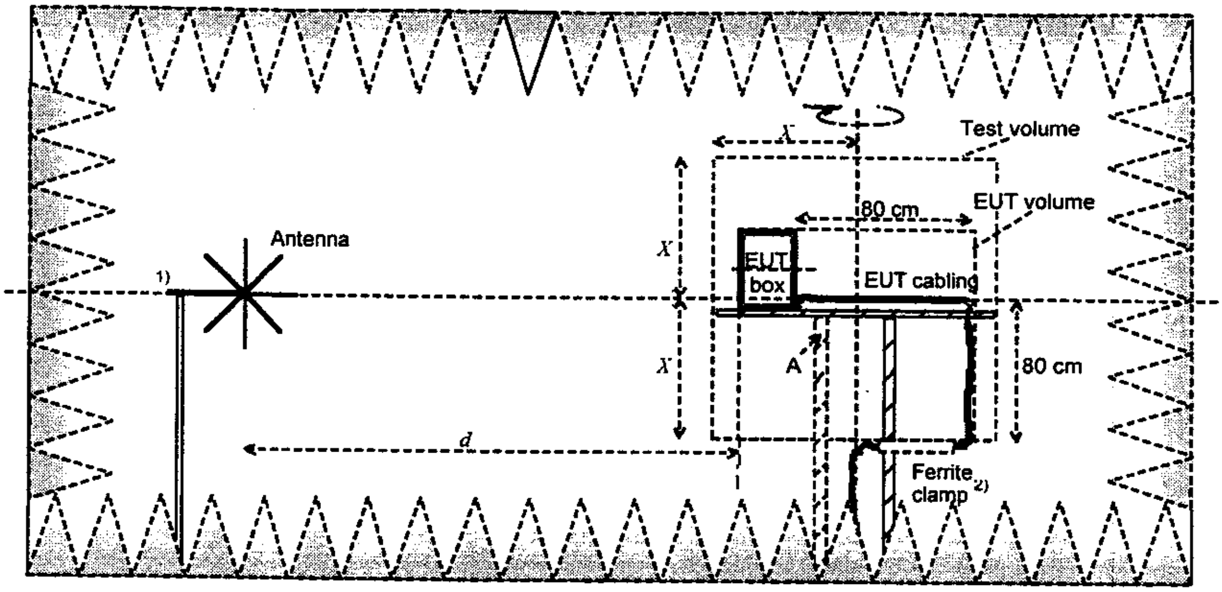
To improve the measurement repeatability, the following guidelines shall be taken into account:

The EUT (including the cables laid out according to 2.6.2.9.2.3) shall be placed so that its centre is at the same height as the centre of the test volume. A non-conductive support of a suitable height may be used to achieve this.

Where it is not physically possible to elevate a large EUT to the centre of the test volume (Figures 19 and 20), the EUT may remain on a non-conductive transport pallet during the test (Figure 21). The height of the pallet shall be recorded in the test report.

Figures 19 and 20 illustrate the set-up of several types of EUT in the FAR.

[1] In preparation.



A = turntable and EUT-support

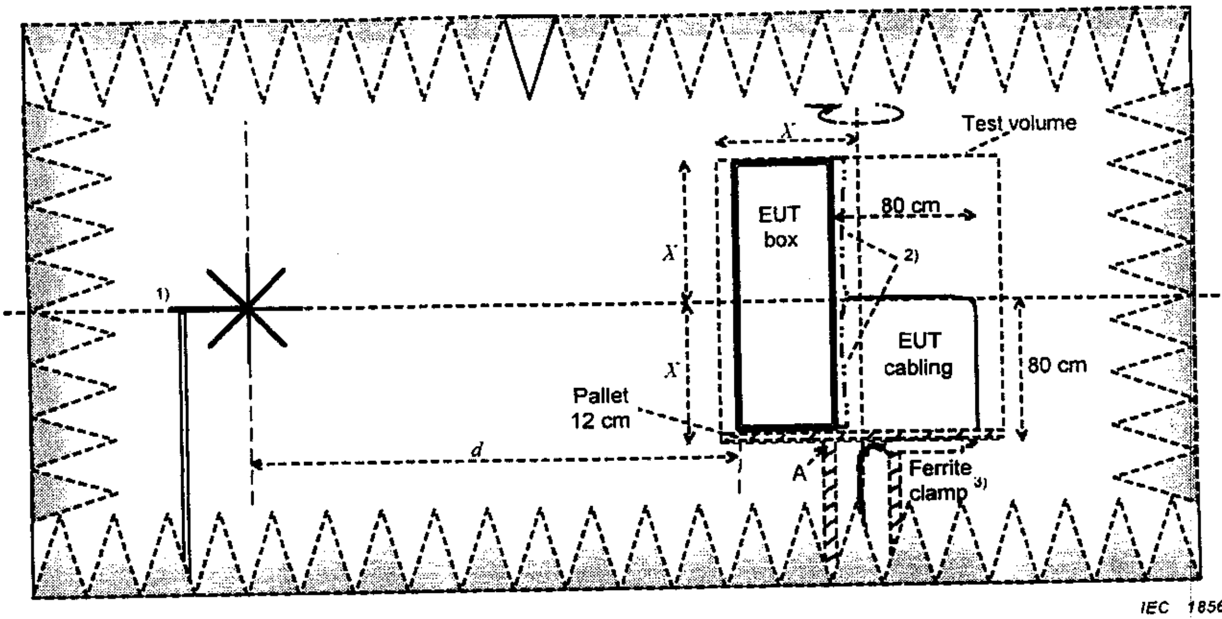
$2X$ = 1,5 m; 2,5 m, 5 m

d = 3 m; 5 m or 10 m (for 3 m, 5 m, or 10 m test distance, respectively)

1) The antenna cable layout shall be the same as in the validation procedure (see Figure 19).

2) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 20 – Typical test set-up for table-top equipment within the test volume of a FAR



A = turntable and EUT-support 2X = 1,5 m; 2,5 m, 5 m

(d = 3 m; 5 m or 10 m for 3 m, 5 m, or 10 m test distance, respectively)

Pallet of 12 cm (10 cm to 14 cm) is a compromise between metal- and wooden ground (see 8.1.2 of CISPR 22:1997)

1) The antenna cable layout shall be the same as in the validation procedure (see Figure 19).

2) The cable layout depends on the location of the cable outlets and shall be close to the surface of the housing

3) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 21 – Typical test set-up for floor standing equipment within the test volume of a FAR

The installation specifications for some floor standing equipment require the unit to be installed and bonded directly to a conductive floor. The reader is advised of the following notes for testing of floor standing equipment in a FAR:

Results showing non-compliance to a FAR limit of floor standing equipment that is intended to be installed and bonded directly to a conductive floor may be lower if tested on a ground plane that better simulates the final installation environment. This may apply especially for emissions at frequencies below 200 MHz, in horizontal polarisation, and at emission source heights (in the EUT) corresponding to a height of 0,4 m or less above ground in a typical installation. The reader is advised that prior to a determination of non-compliance based on FAR measurements, additional investigation in a ground plane test environment (i.e. an Open Area Test Site or Semi-Anechoic chamber) is recommended to better simulate the equipment's intended installation condition.

2.6.2.9.2.3 Cable layout and termination

In EMC testing the reproducibility of measurement results is often poor due to differences in cable layout and termination, when one single EUT is measured at various test-sites.

The following listed items are general conditions of the test set up in order to provide good reproducibility (see Figures 20 and 21). Ideally, all radiation to be measured should only be emitted from the test volume. The cables used during the test shall be in accordance with manufacturer's specifications. If such cables are not available, the specifications of the cables used during testing shall be clearly described in the test report.

The cables that are connected to the EUT and ancillary equipment or power supply shall include a length of 0,8 m run horizontally and 0,8 m run vertically (without any bundling) inside the test volume (see Figure 20 and 21). Any cable length in excess of 1,6 m with a relative tolerance of ±5 % shall be routed outside the test volume.

If the manufacturer specifies a shorter length than 1,6 m, then where possible, it shall be oriented such that half of its length is horizontal and half is vertical in the test volume.

Cables that are not exercised through ancillary equipment during the test must be appropriately terminated:

- coaxial (shielded) cables with coaxial terminator with correct impedance (50 Ω or 75 Ω);
- shielded cables with more than one inner wire must have common mode (line to reference earth/ground) and differential-mode (line to line) termination in accordance with the manufacturer's specifications;
- unshielded cables must have differential mode termination as well as common-mode termination in accordance with the manufacturer's specifications.

If the EUT needs ancillary equipment in order to be operated properly, special care has to be taken that no emission of that equipment can influence the radiated emission measurement. Ancillary equipment shall be located outside the screened room wherever possible. Measures against RF-leakage into the FAR through the interconnection cables must be taken.

The test set-up including cable layout, specifications of attached cables and terminations, measures taken to suppress the emission influence of the cable length outside the test volume (for instance the use of ferrite clamps) are specified in the different product standards.

Due to the different nature of the many possible EUTs, product standards may deviate considerably from this subclause, (e.g. 10.4 of CISPR 22:1997).

2.6.2.10 Measurements in TEM cells

(Under consideration)

2.6.3 Field-strength measurements in the frequency range 1 GHz to 18 GHz

2.6.3.1 Quantity to measure

The electric field strength emitted by the EUT at the measuring distance is the quantity to measure. The result shall be expressed in terms of field strength.

NOTE In some standards, emission limits for equipment are expressed in terms of ERP (effective radiated power) in dB(pW) above 1 GHz. Under free space far field conditions, the formula to convert ERP into field strength at a 3 m distance is:

$$E_{(3m)}/\text{dB}(\mu\text{V/m}) = \text{ERP}/\text{dB}(\text{pW}) + 7{,}4$$

For distances d other than 3 m:

$$E_d/\text{dB}(\mu\text{V/m}) = \text{ERP}/\text{dB}(\text{pW}) + 7{,}4 + 20 \log [3/(d/\text{m})]$$

2.6.3.2 Measurement distance

The field strength emitted by the EUT is measured at a preferred distance of 3 m.

Other distances may be used in practical situations:

- shorter distances in the case of high ambient noise, or to reduce the effect of unwanted reflections, but care should be taken to ensure the measurement distance is greater than or equal to $D^2/2\,\lambda$ (see 5.5.6 of CISPR 16-1);

– greater distances for large EUTs to allow the antenna beam to encompass the EUT.

In case of dispute, measurements performed at 3 m shall take precedence.

NOTE Since dominant disturbances of the EUT may be assumed to be incoherent and radiated from a point source, the minimum distance mentioned above ($D^2/2\ \lambda$) is to be applied to the measuring antenna and not to the EUT.

2.6.3.3 Set-up of the equipment under test (EUT)

As a general guideline, the EUT set-ups used for measurements below 1 GHz should as much as possible also be used above 1 GHz.

2.6.3.4 Measurement procedure

2.6.3.4.1 Encompassing of the EUT by the measuring antenna

Radiated emissions measurements above 1 GHz are made using calibrated linearly polarized antennas, which may have a smaller beam width (major pattern lobe) than the antennas used for frequencies below 1 GHz. The width of the main lobe of the antenna, that is defined as the 3 dB beam width of the antenna (see 5.5.6 of CISPR 16-1), shall be known for every antenna used so that, when large EUTs are tested, the area of coverage of the EUT can be determined. Moving the measurement antenna over the surfaces of the sides of the EUT or another method of scanning of the EUT is required when the EUT is larger than the beam width of the measuring antenna. When radiated measurements are made at the limit distance and the measurement antenna does not completely encompass a large EUT at that distance, additional measurements at a greater distance may be necessary to demonstrate that emissions were maximum at the limit distance.

NOTE When determining the encompassing of the EUT by the antenna beam width, the surface of the EUT being considered shall include one wavelength (at the lowest frequency, i.e. 1 GHz) of the cables coming out of the EUT.

2.6.3.4.2 General measurement procedure

For any EUT, the frequencies of emission should first be detected by a preliminary emission maximization (see 2.6.3.4.3). Then the final emission test takes place (see 2.6.3.4.4). Both of these measurements are to be made preferably at the limit distance. If, for any justified reason, the final measurement is performed at a different distance than the limit distance, a measurement at the limit distance should be made first, to help in interpreting the resulting data in case of dispute.

In performing these measurements, the sensitivity of the measurement equipment relative to the limit shall be determined before the test. If the overall measurement sensitivity is inadequate, low noise amplifiers, closer measurement distances or higher gain antennas may be used. If closer measurement distances or higher gain antennas are used, the beam width versus size of the EUT shall be taken into account. Also, measurement system overload levels shall be determined to be adequate when preamplifiers are used.

Burn out and saturation protection for the measuring instrumentation is required when low level emissions are to be measured in the presence of a high level signal. A combination of bandpass, bandstop, lowpass and highpass filters may be used. However, the insertion loss of these or any other devices at the frequencies of measurement shall be known and included in any calculations in the report of measurements.

NOTE A simple method of determining whether non-linear effects (overload, saturation, etc.) occur consists of inserting a 10 dB attenuator at the input of the measurement instrument (ahead of any pre-amplifier if one is used) and verifying that the amplitude of all the harmonics of the high amplitude signal (that may cause non-linear effects) is reduced by 10 dB.

2.6.3.4.3 Preliminary emission maximization

The maximum radiated emission for a given mode of operation may be found during a preliminary test, using the following step by step procedure:

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a) Monitor the frequency range of interest at a fixed antenna height and polarization (horizontal or vertical), and EUT azimuth.

b) Note the amplitude and frequency of the maximum signal met.

c) Rotate the EUT 360° to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 2 dB or more, go back to the azimuth and repeat step b). Otherwise, orient the EUT azimuth to repeat the highest amplitude observation and proceed.

   NOTE 1 Alternatively, instead of rotating the turn-table where the EUT stands, it is also possible to rotate the receiving antenna around the EUT.

d) Move the antenna over a given range of travel (height search to be defined for each product or product family; in any case, 1 m to 4 m should be the maximum range for this height search) to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 2 dB or more, return to step b) with the antenna fixed at this height. Otherwise, move the antenna to the height that repeats the highest amplitude observation and proceed.

e) Change the antenna to the other polarization and repeat steps b) through d). Compare the resulting suspected highest amplitude signal with that found for the other polarization. Select and note the higher of the two signals. This signal is termed the highest observed signal with respect to the limit for this EUT operational mode.

f) The effects of the various operational modes of the EUT shall be examined. One way to do this is to vary the operating mode of the equipment as steps b) through e) are being performed.

g) After completing steps a) through f), record the final EUT configuration and mode of operation (corresponding to the maximum radiated emission) to use for the final radiated emissions test.

NOTE 2 The procedure described in this subclause is proposed in the general case. However, noting that it may be extremely time-consuming to perform, product committees are requested to check and adapt it to their specific case. The following two elements can serve as a basis for simplifying the method:

- the EUT shall be rotated horizontally unless it has been determined that for the particular product or product family the emission comes predominantly from one direction or is omni-directional;
- the height search of the antenna may be limited to a certain angle or distance above and below the EUT, or even be suppressed (horizontal measurements only) if it can be determined that for the particular product or product family the emission is maximum in or close to the horizontal plane.

2.6.3.4.4 Final emission test

The field strength emitted by the EUT at the given measurement distance is measured using the configuration (antenna height, EUT azimuth, etc.) producing the maximum emission, as identified during the preliminary emission maximization (the receiving antenna being aligned with this maximum emission).

This final measurement shall be the result of a maximum hold on the spectrum analyzer during a given time proportional to the frequency span used. This given time should be defined for each product or product family, taking into account the duration of the operating modes and the time constants associated with each specific product to be tested.

2.6.4 Substitution method of measurement in the frequency range of 30 MHz to 18 GHz

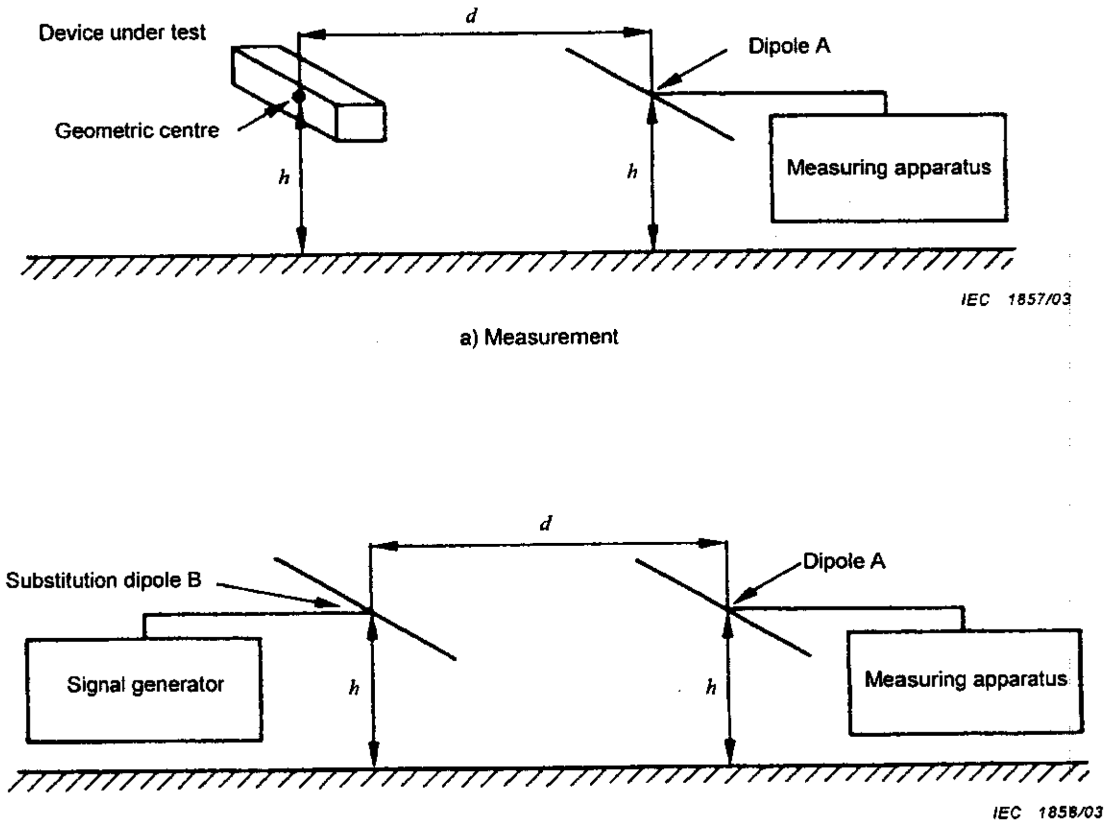
The method is intended for measuring radio disturbance radiated from the cabinet, including wiring and circuitry inside the cabinet, of an equipment under test. The EUT may be either a self-contained unit with no port for any connection or have one or several ports for power and other external connections.

The substitution method is currently being used to measure emissions from microwave ovens in the frequency range 1 GHz –18 GHz.

For future product standards, product committees are invited to use the field-strength measurement method described in 2.6.3.

2.6.4.1 Test site

The test site shall be a level area. Indoor sites may be used, but may need special arrangements, especially in the upper part of the frequency range, in order to meet the requirements of stable and non-critical reflections from the surroundings – for example, a corner reflector added to the measuring antenna and an absorbing wall behind the EUT. The suitability of the site shall be determined as follows (see Figure 22).



a) Measurement

b) Calibration

Figure 22 – Method of measurement – Substitution method (see 2.6.4.1 and 2.6.4.3)

Two horizontal half-wavelength dipoles (see also 2.6.4.2) shall be placed parallel to each other, at the same height *h*, being not less than 1 m above the floor and spaced at the measurement distance *d*. Dipole B shall be connected to a signal generator and dipole A to the input of the measuring receiver. The signal generator shall be tuned to give maximum indication on the measuring receiver and its output adjusted to a convenient level. The site shall be considered suitable for the purpose of measurement at the test frequency if the indication on the measuring receiver does not vary more than ±1,5 dB when dipole B is moved 100 mm in any direction. The test shall be repeated throughout the frequency range at frequency intervals small enough to ensure that the site is satisfactory for all measurements intended.

If an EUT requires that measurements be made also with vertical polarization (see 2.6.4.3), the suitability test of the site shall be repeated with the two dipoles positioned for vertical polarization.

2.6.4.2 Test antennas

The test antennas A and B have been described above as half-wave dipoles. For the frequency range below 1 GHz, this requirement applies primarily to the transmitting antenna B for which the radiated power in the direction of maximum radiation must be relatable to the power at the terminals of antenna B. The measuring antenna A should also be a half-wave dipole. Its actual sensitivity will be included in the substitution calibration of the test configuration.

In the frequency range of 1 GHz to 18 GHz linearly polarized horn antennas are recommended.

2.6.4.3 EUT configuration

The EUT shall be placed on a non-conducting table with provision to rotate in the horizontal plane. The EUT shall be set up so that the geometric centre of the EUT coincides with the point earlier used as centre point for dipole B (Figure 22). If the EUT is comprised of more than one unit, each unit shall be measured separately. Detachable leads to the EUT should be removed if operation is not affected adversely. Required leads shall be provided with absorbing ferrite rings and be so positioned that they will not influence the measurements. For shielded EUTs, all connectors not used shall be terminated by shielded terminations.

2.6.4.4 Test procedure

With the EUT arranged as described in 2.6.4.3, the horizontally polarized measuring dipole A shall be placed in the same position as when checking the test site. The dipole shall be normal to a vertical plane through its centre and that of the EUT. The EUT is first measured in its normal table-standing position and secondly when tilted 90° to stand on a normally vertical side. In each position it shall be rotated 360° in the horizontal plane. The highest reading Y shall be the characteristic value for the EUT.

The measuring system is calibrated by replacing the EUT with a half-wave dipole B. The centre of this calibrating dipole B shall be placed in the same spot as the geometric centre of the previously measured EUT and parallel with the measurement antenna A, and be connected to a signal generator. The radiated power from the cabinet of the EUT is defined as the power at the terminals of the half-wave dipole B when the signal generator is adjusted to give the same reading on the measuring receiver as the maximum reading recorded earlier (Y), at each frequency of measurement.

When measurements are made with both horizontally and vertically polarized measuring dipoles, separate calibrations must be made for the two modes.

2.6.5 Measurements of *in situ* equipment

2.6.5.1 Applicability of and preparation for *in situ* measurements

In situ measurements may be necessary for the investigation of an interference problem at a particular location, i.e. where electrical equipment is suspected of causing interference to radio reception in its vicinity.

Where allowed by the relevant product standard, *in situ* measurements may be made for the evaluation of compliance, if it is not possible for technical reasons to make radiated emission measurements on a standard test site. Technical reasons for *in situ* measurements are excessive size and/or weight of the EUT or situations where the interconnection to the infrastructure for the EUT is too expensive for the measurement on standard test sites. *In situ* measurement results of an EUT type will normally deviate from site to site or from results obtained on a standard test site and can therefore not be used for type testing.

NOTE 1 In general, however, due to imperfections such as mutual coupling between the conductive structures present in the *in situ* environment, which may also be more or less polluted by ambient electromagnetic fields, and the measuring antenna/equipment under test, *in situ* measurements cannot fully replace measurements on a suitable test site (open-area test site or alternative test sites, for example, (semi-)anechoic chambers) as specified in CISPR 16-1.

The EUT usually consists of one or more devices and/or systems, is part of an installation, or is interconnected with an installation.

A perimeter connecting the outer parts of the EUT is usually taken as the reference point to determine the measurement distance. In some product standards, the exterior walls or boundaries of business parks or industrial areas are taken as the reference points.

Preliminary measurements shall be made to identify the frequency and amplitude of the disturbance field strengths amongst the ambient signals taking into account the potential sources of interference (for example, oscillators) in the EUT. For these measurements the use of a spectrum analyser is recommended in place of a receiver because a large frequency spectrum can be analysed. For the identification of the frequency and amplitude of the disturbance signals the use of a current probe on the connected cables, or near-field probes or the measurement antennas placed closer to the EUT is recommended.

Measurements shall also be made on selected frequencies to determine, where possible, the modes of operation in which the EUT generates the highest disturbance field strengths. The subsequent measurements shall be made with the EUT in these modes of operation.

NOTE 2 Where the EUT is a piece of equipment, the operating mode of which cannot be switched independently of the operation of other equipment, the selection of conditions producing the highest disturbances may be impossible. For some of them, these conditions may be dependent on time, particularly if they are on cyclic operation. In such cases, the period of observation should be chosen to approach the conditions of highest disturbance production.

Measurements shall be made around the EUT at approximately the same measurement distance on each of the selected frequencies to determine the direction of the highest disturbance field strength. The EUT should be tested in at least three different directions. The final disturbance field-strength measurements on each frequency shall be made in the directions of the highest disturbance field strengths (which may vary from frequency to frequency) taking into account the local conditions.

The highest disturbance field strengths shall be measured with the antenna in vertical and horizontal polarization.

If the ratio of the measured disturbance field strength to any ambient emission is lower than 6 dB, the measurement methods described in Annex E can be used.

2.6.5.2 Field-strength measurements in the frequency range 9 kHz to 30 MHz

2.6.5.2.1 Measurement method

The magnetic disturbance field strength shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength.

The horizontally polarized disturbance field strength shall be measured at the standard measurement distance d_{limit} using a loop antenna as described in 5.5.2.1 of CISPR 16-1 at a height of 1 m (between the ground and lowest part of the antenna). The maximum disturbance field strength shall be determined by rotating the antenna.

NOTE For the measurement of the maximum disturbance field strength from lines arranged in any direction, the antenna should be oriented in three orthogonal directions, and the measured field strength is calculated by

$$E_{\text{sum}} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

In cases where limits are given for the E field equivalent but the measured field strengths are the magnetic components, the H field strength can be converted to the corresponding E field strength using the free space impedance of 377 Ω by multiplying the H field reading by 377. The H field in this case is given by

$$H_{\text{sum}} = \sqrt{H_x^2 + H_y^2 + H_z^2}$$

This H field value can be used directly in cases where limits are directly given for the magnetic field strength.

If the antenna cannot be moved in three orthogonal directions, it can be turned by hand in the direction of maximum reading for the measurement of the maximum disturbance field strength.

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2.6.5.2.2 Measurement distances other than the standard distance

If it is not possible to adhere to the standard distance d_{limit}, as specified in the product or generic standard, the measurements should be made at distances either less or greater than the standard measuring distance in the direction of the maximum radiation.

At least three measurements at different measuring distances less or greater than the standard measuring distance shall be used if it is not possible to use the standard distance.

The measurement results (in decibels) shall be plotted as a function of the measurement distance on a logarithmic scale. One line shall be drawn to join up the measurement results. This line represents the decrease in the field strength and can be used to determine the disturbance field strength at distances other than the measurement distance, for example, at the standard distance.

2.6.5.3 Field-strength measurements in the frequency range above 30 MHz

2.6.5.3.1 Measurement method

The electric disturbance field strength shall be measured in the direction of maximum radiation at the standard distance with the EUT in the mode of operation generating the highest disturbance field strength. The maximum horizontally and vertically polarized disturbance field strengths shall be measured using broadband antennas with, as far as practicable, a variable height of 1 m to 4 m. The highest value shall be taken as the measured value.

It is recommended that biconical antennas be used for measurements in the frequency range up to 200 MHz and log-periodic antennas for measurements in the frequency range above 200 MHz. The distance between the measuring antenna and any nearby metallic elements (including cables) should be greater than 2 m.

2.6.5.3.2 Measurement distances other than the standard distance

The standard measurement distance d_{std} is specified in the product or generic standard. If it is not possible to adhere to the standard measurement distance, the disturbance field strength shall be measured in different measuring distances as described in 2.6.5.2.2. A height scan of the antenna shall be used for each measurement The disturbance field strength at the standard distance d_{std} shall be determined according to 2.6.5.2.2 by plotting the measured field strength as a function of the measurement distance on a logarithmic scale.

If it is not possible to measure at different measuring distances and the measurement distance refers to the outer wall of a building or the border of the premises, the measurement results shall be converted to the standard distance using equation (5).

$$E_{std} = E_{mea} + n \times 20 \times \log \frac{d_{mea}}{d_{std}} \tag{5}$$

where

E_{std} is the field strength at the standard distance in dB(μV/m) for comparison with the emission limit;

E_{mea} is the field strength at the measurement distance in dB(μV/m);

d_{mea} is the measurement distance in metres;

d_{std} is the standard distance in metres.

n depends on the distance d_{mea} as follows:

if	$30\ \text{m} \le d_{mea}$,	$n = 1$;
if	$10\ \text{m} < d_{mea} < 30\ \text{m}$	$n = 0{,}8$;
if	$3\ \text{m} < d_{mea} < 10\ \text{m}$	$n = 0{,}6$.

NOTE $n < 1$ accommodates the difference between the measuring distance and the distance to the EUT.

Measurement distances closer than 3 m shall not be used.

If it is not possible to measure at different measuring distances, and equation (5) is not used because the measurement distance does not refer to the outer wall of a building or boundary of premises, the field strength should be determined by measurement of the radiated disturbance power (see 2.6.5.4).

2.6.5.4 *In situ* measurement of the effective radiated disturbance power using the substitution method

2.6.5.4.1 General measurement condition

The substitution method can be used without additional conditions if, and only if, the EUT can be switched off and if the EUT can be removed for the substitution.

If the EUT cannot be removed, and if its front face is a large plane surface, the effect of this face on the substitution shall be taken into account (see equation (7b)). If the front surface of the EUT does not fit into a two-dimensional plane in the measurement direction, the additional measurement uncertainty is not considered.

If the EUT cannot be switched off, it is still possible to use the substitution method to measure the radiated power of a disturbance from the EUT at a particular frequency, by using a nearby frequency at which the field strength of the disturbance from the EUT is at least 20 dB below that at the frequency of interest ("nearby" means within one or two receiver IF-bandwidths). The frequency selected should, where possible, be chosen with regard to possible interference to radio services.

2.6.5.4.2 Frequency range 30 MHz to 1 000 MHz

2.6.5.4.2.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. This requirement is generally met, if

a) d is greater than $\dfrac{\lambda}{2\pi}$ and

b)
$$d \geq \frac{2 \times D^2}{\lambda} \tag{6}$$

where

d is the measurement distance in meters;

D is the maximum dimension of the EUT with cabling in meters;

λ is the wavelength in meters;

or

the measurement distance d is equal to, or greater than, 30 m.

In the far field the exponent n in equation (5) may be assumed to be 1. If a shorter measurement distance is chosen, this assumption can be validated by using the procedure of 2.6.5.3.2 to verify that the field strength falls off inversely with distance.

If the local conditions require that a shorter measurement distance be chosen, this shall be indicated.

2.6.5.4.2.2 Measurement method

The effective radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. The measurement distance shall be chosen according to 2.6.5.4.2.1 and the highest disturbance field strength on the selected frequency determined by varying the antenna height at least in the range of 1 m to 4 m as far as practicable.

For the measurement of the effective radiated disturbance power, steps a) to g) shall be followed.

a) The EUT shall be disconnected and removed. A half-wave dipole or antenna with similar radiation characteristics and known gain G, relative to a half-wave dipole is substituted in its place. If it is impractical to remove the EUT, a half-wave or broadband dipole (in the frequency range lower than about 150 MHz to minimize mutual coupling to the EUT) is positioned in the vicinity of the EUT. The vicinity is a range up to 3 m.

b) The half-wave (or broadband) dipole shall then be fed by a signal generator operating on the same frequency.

c) The position and polarization of the half-wave dipole (or broadband antenna) shall be such that the measuring receiver receives the highest field strength. If the EUT is not removed, then, if possible, it shall be switched off and the dipole is moved in a range up to 3 m around the EUT.

d) The power of the signal generated shall be varied until the measuring receiver shows the same reading as when the highest disturbance field strength from the EUT was measured.

e) If the front of the EUT fills a large plane surface (for example, a building with a cable-TV network) the substitution antenna (half-wave dipole) is positioned about 1 m in front of the plane surface (in front of the building). The location of the substitution should be so chosen that an imaginary line between the substitution antenna and the measuring antenna is perpendicular to the direction of the face of the building.

f) The height, polarization and distance to the plane imaginary surface enclosing the half-wave dipole (or broadband antenna) and perpendicular to the measurement axis between the antenna and the location of the measuring antenna shall be varied such that the receiver receives the highest field strength.

g) The power of the signal generator shall be varied as in d) above.

For removed EUTs and EUTs whose front face is not contained within an imaginary large plane surface, the power at the signal generator P_G plus the gain G of the transmit antenna relative to a half-wave dipole yields the effective radiated disturbance power P_r to be measured:

$$P_r = P_G + G \tag{7a}$$

For EUTs that fit within an imaginary large plane surface (for example, buildings with telecommunication networks), the increase in gain of the dipole positioned in front of this surface is given by

$$P_r = P_G + G + 4 \text{ dB} \tag{7b}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

The effective radiated disturbance power can be used to calculate the disturbance field strength at the standard measurement distance d_{std}. The free-space field strength E_{free} shall be calculated using the following equation:

$$E_{free} = \frac{7\sqrt{P_r}}{d_{std}} \tag{8}$$

where

E_{free} is in µV/m;

P_r is in pW; and

d_{std} is in metres.

If the calculated free-space field strength of equation (8) is compared with limits of disturbance field strength measured in standard test sites, it must be considered that the amplitude field strength measured at standard test sites is approximately 6 dB higher than the free space field strength of equation (8) due to the reflections from the ground plane. Equation (8) can be modified to take into account this increment. The disturbance field strength at the standard distance E_{std} can therefore be calculated for the vertical polarization using the following equation:

$$E_{std} = P_r - 20 \log d_{std} + 22{,}9 \tag{9a}$$

For horizontal polarization below 160 MHz the maximum field strength is not measured at standard test sites. Therefore the 6 dB factor must be corrected as follows:

$$E_{std} = P_r - 20 \log d_{std} + 16{,}9 + (6 - c_c) \tag{9b}$$

where

E_{std} is in dB(µV/m);

f is the measuring frequency;

d_{std} is in metres;

c_c is the correction factor for horizontal polarization. This was determined assuming the radiation source at 1 m in height.

f MHz	30	40	50	60	70	90	100	120	140	160	180	200	750	1 000
c_c dB	11	10,2	9,3	8,5	7,6	5,9	5,1	3,4	1,7	0	0	0	0	0

This method for determining the disturbance field strength can mainly be used if there are obstacles between the measuring antenna and the EUT.

2.6.5.4.3 Frequency range 1 GHz to 18 GHz

2.6.5.4.3.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. The far-field condition shall be verified by measuring the radiated disturbance power with a double-ridged waveguide horn or log-periodic antenna as a function of the distance. The requirement is met if the measurement distance is equal to, or greater than, the transition distance. The transition distance is marked by the transition point which shall be determined as shown in Figure 23. The measurement results shall be plotted and two parallel lines separated by 5 dB drawn to enclose as many of the measurement results; the transition point is the point where the lines intersect and after which the radiated power decreases by 20 dB/decade.

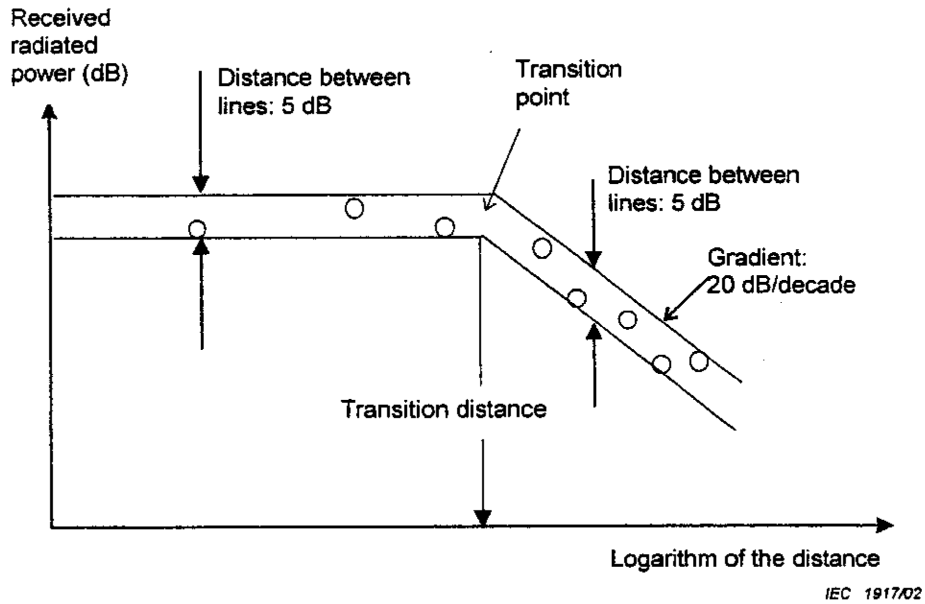

Figure 23 – Determination of the transition distance

2.6.5.4.3.2 Measurement method

The radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. A double-ridged waveguide horn or log-periodic antenna shall be used to determine the direction of maximum radiation. The measurement distance shall then be chosen according to 2.6.5.4.2.1 and the disturbance field strength on the selected frequency is measured. The antenna position shall be varied slightly to ensure that the measured field strength is not at a local minimum (due, for example, to reflections).

For the measurement of the radiated disturbance power the EUT shall be disconnected and a double-ridged horn or log-periodic antenna positioned either in the immediate vicinity of the EUT or in its place. The antenna shall then be fed by a signal generator operating at the same frequency. The orientation of the antenna shall be such that the test receiver receives the highest field strength. This antenna position shall be fixed. The power of the signal generated shall be varied until the test receiver receives the same power as that generated by the EUT. The power at the signal generator P_G plus the gain G of the transmitting antenna relative to a half-wave dipole yields the required radiated disturbance power P_r:

$$P_r = P_G + G \tag{10}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

2.6.5.5 Documentation of the measurement results

The particular circumstances and conditions of the *in situ* measurements should be documented to enable the operational conditions to be reproduced if the measurements are repeated. The documentation should include

- reasons for the *in situ* measurement instead of using a standard test site;
- description of the EUT;
- technical documentation;
- scale drawings of the measurement site, showing the points at which measurements were made;
- description of the measured installation;
- details of all connections between the measured installation and the EUT: technical data and details of their location/configuration;
- description of the operating conditions;
- details of the measuring equipment;
- measurement results:
  - antenna polarization;
  - measured values: frequency, measured level and disturbance level;

    NOTE The disturbance level is the level referred to the standard measuring distance.
  - assessment of the degree of interference (if applicable).

2.6.6 Measurement in a loop antenna system

The loop antenna system (LAS) considered in this subclause is suitable for indoor measurement of the magnetic field strength emitted by a single EUT in the frequency range 9 kHz to 30 MHz. The magnetic field strength is measured in terms of the currents induced into the LAS by the magnetic disturbance field of the EUT.

The LAS shall be validated regularly using the method described in Clause G.4 of CISPR 16-1, Annex G. That annex also gives a complete description of the LAS and a relation between the measuring results obtained with the LAS and those obtained as described in 2.6.2.

2.6.6.1 General measurement method

Figure 24 shows the general concept of measurements made with the LAS. The EUT is placed in the centre of the LAS. The current induced by the magnetic field from the EUT into each of the three large loop antennas of the LAS is measured by connecting the current probe of the large loop antenna to a measuring receiver (or equivalent). During the measurements the EUT remains in a fixed position.

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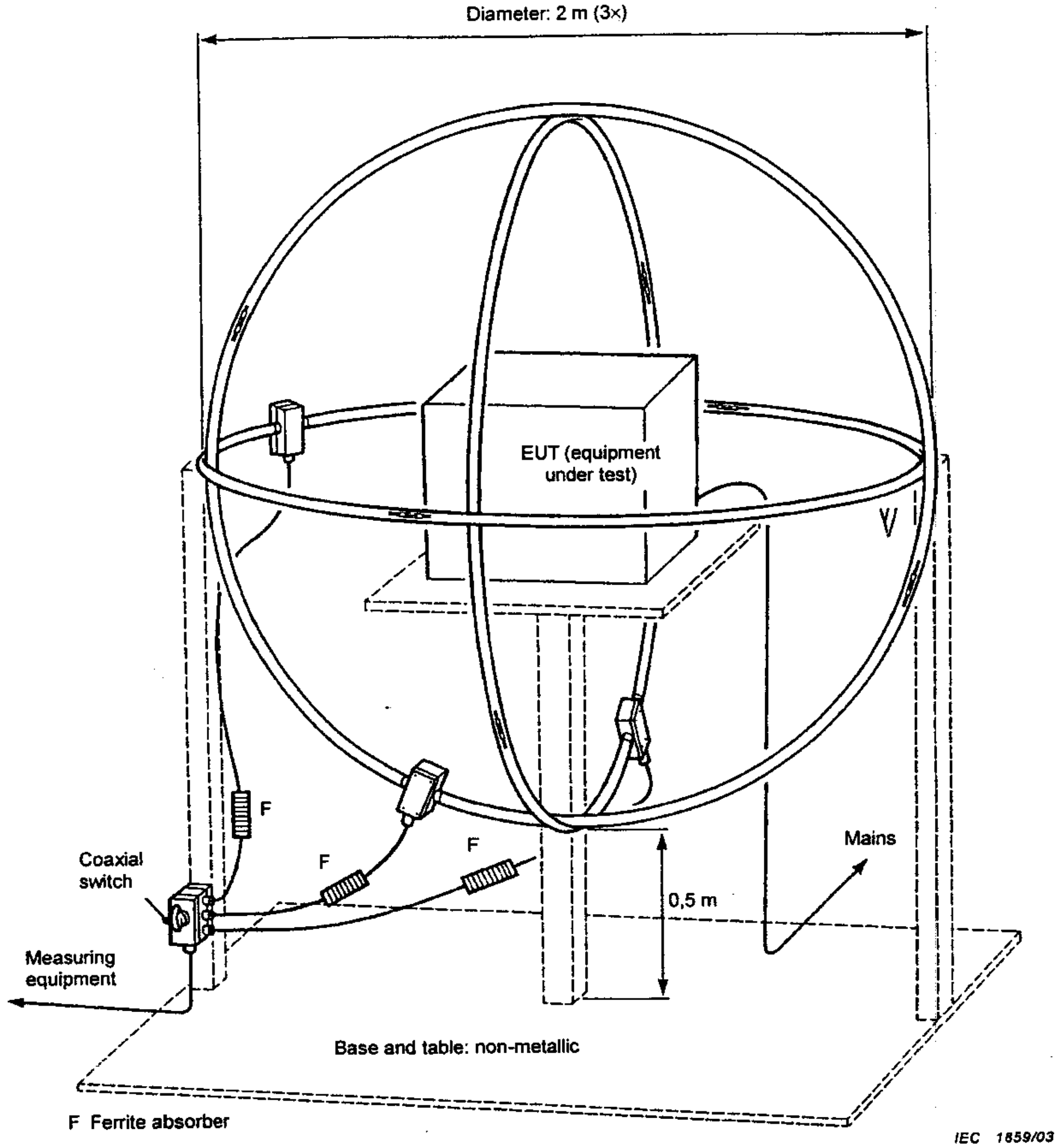

Figure 24 – Concept of magnetic field-induced current measurements made with the loop antenna system (see 2.6.6)

The currents in the three large loop antennas, originating from the three mutually orthogonal magnetic field components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dBμA, as specified in the product standard.

The emission limit shall apply to a LAS having large loop antennas with the standardized diameter of 2 m.

2.6.6.2 Test environment

The distance between the outer perimeter of the LAS and nearby objects, such as floor and walls, shall be at least 0,5 m.

The currents induced in the LAS by an RF ambient field shall be judged in accordance with 5.6.4 of CISPR 16-1.

2.6.6.3 Configuration of the equipment under test

To avoid unwanted capacitive coupling between the EUT and the LAS, the maximum dimensions of the EUT shall allow a distance of at least 0,20 m between the EUT and the standardized 2 m large loop antennas of the LAS.

The position of the mains lead shall be optimized for maximum current induction. In general, this position will not be critical when the EUT complies with the conducted emission limit.

In case of a large EUT, the diameter of the loop antennas of the LAS may be increased up to 4 m. In that case:

a) the current values measured shall be corrected in accordance with Clause I.6 of CISPR 16-1; and

b) the maximum dimensions of the EUT shall allow a distance between the EUT and the large loops of at least 0,1 × *D* m, where *D* is the diameter of the non-standardized loop.

Section 3: Immunity measurements

3.1 Immunity test criteria and general measurement procedures

Immunity measurements are based upon a judgement of the point when the effect of interference on the EUT (equipment under test) has reached a specified level.

Immunity measurements are performed in general by the application of a wanted test signal and an unwanted signal to the EUT. The fundamental basis of the measurement is set out in this clause, together with a listing of conditions which need to be specified in the detailed recommendations produced by the CISPR product committees. Sublause 3.2 deals with the general principals of conduction methods of measurement for immunity, and 3.3 with radiation methods.

3.1.1 General measurement method

Figure 25 sets out the fundamental concept upon which all methods of measurement of immunity are based.

The EUT is set up as specified to represent normal operating conditions. The unwanted signal is applied with increasing severity until the prescribed performance degradation is detected or the specified immunity level is reached, whichever is lower.

The unwanted signal may be introduced by direct radiation or by current/voltage injection. In most cases both the direct radiation and injection techniques will be needed to fully assess the immunity potential of EUTs. The injection method is most useful for frequencies under 150 MHz, although direct radiated tests above approximately 30 MHz are used. The direct radiated tests can be performed using fields launched by antennas and intercepted by the EUT. In some cases a "bounded" field is most efficient for EUTs of height less than 1 m. Examples of bounded fields occur with TEM cells, stripline antennas and mode-stirred enclosures.

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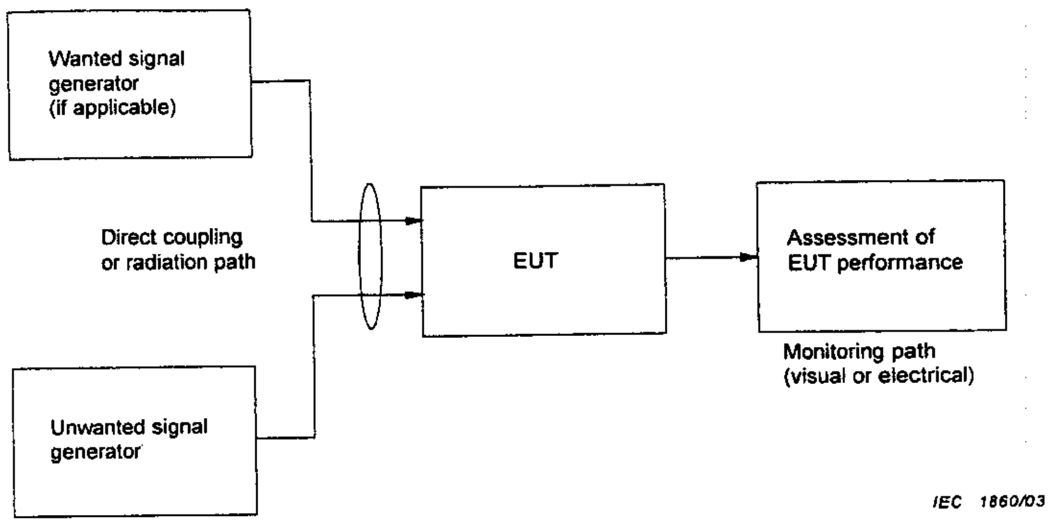

Figure 25 – Fundamental concept of immunity measurement (see 3.1.1)

3.1.1.1 Objective assessment of performance degradation

Objective assessment of EUT immunity is made by monitoring voltages, currents, specific signals, audio rectification levels, etc., which can be recorded using analogue or digital recording techniques.

As an example of one such assessment of performance degradation, the immunity of television receivers to AM modulated RF interference is presented below.

First the wanted test signal only is applied to the EUT. This produces a wanted audio signal which is measured. The control of the EUT or test set-up is adjusted to set this audio signal at the required level. The wanted audio signal is then removed either by switching off the modulation or the audio test signal. The unwanted signal is applied in addition and its level is adjusted to obtain an unwanted audio signal at the specified level below the wanted audio signal level. The level of the unwanted signal is the measure of immunity of the EUT at the test frequency concerned. Care should be taken in order not to damage the EUT by too high levels of the unwanted signal.

3.1.1.2 Subjective assessment of performance degradation

Subjective assessment of EUT immunity is made by visual and/or aural monitoring of performance degradation for EUTs with such visual or aural or both presentations. This technique differs from that in 3.1.1.1 in that specific electrical or similar signals and levels are not directly recorded with an analogue or digital format. Instead, performance degradation is not formulated in measurable terms but in human sensory terms, e.g., human audio or visual perception of an annoying effect. The unwanted immunity signals can be the same or similar to those used for objective immunity assessment measurements.

As an example of one such subjective assessment of performance degradation, the immunity of television receivers to an unwanted signal, as perceived by humans as degraded visual and aural presentations, is given below.

In the case of picture interference, the wanted test signal produces a standard picture and the unwanted signal produces a degradation of the picture. The degradation may be in a number of forms, such as a superposed pattern, sync disturbance, geometrical distortion, loss of picture contrast or colour, etc.

The criterion of what constitutes performance degradation needs to be prescribed, and the conditions under which the subjective assessment is to be made must be specified.

First the wanted signal only is applied to the EUT. The controls of the EUT are set to obtain a picture of normal brightness, contrast and colour saturation. The unwanted signal is then applied in addition and its level adjusted to obtain degradation of the picture as perceived by a human watching the picture. This level is the measure of immunity of the EUT at the test frequency concerned.

3.1.1.3 Measurement to a limit

The actual measurement of the immunity may not be required, i.e., when it is sufficient to know whether the EUT meets a limit or not. The unwanted signal, instead of being adjusted at each test frequency, is kept at the level of the limit and its frequency swept through the test range. The EUT is considered to meet the limit if no degradation, whether objective or subjective, is observed at any time. This procedure is called a "go/no-go" test.

3.1.2 Immunity degradation criteria

To establish reasonable immunity criteria will require defining what is meant by performance degradation. One such view of the progressiveness of performance degradation may be as follows:

a) *no degradation:* equipment complies with its design specifications. This type of criterion shall be adopted for sensitive health and safety equipment, as well as services with impact on large populations of consumers. It might conceivably be used as an immunity criterion for some critical processes or equipment operation as well;

b) *noticeable degradation:* in this case, the performance has been affected by an EM disturbance. Increased noise in video and audio circuits, decreased signal-to-noise ratio in control circuits, error rates in digital systems approaching an allowable system maximum, or annoying audio or visual disturbances are examples of noticeable degradation. No operator intervention should be required to continue use of the electronic product/equipment. This degradation is generally used for mass produced products. The degradation disappears when the immunity signal is removed;

c) *serious degradation:* in this category, products will not be able to provide continuous satisfactory operation. To correct this, field engineering or customer service representatives will spend considerable time in the field trying to identify and correct the problem. This immunity level should be set so that it occurs on very rare occasions. Operator intervention is required to restore specific operation of electronic product/equipment such as system lockups, resets, indiscriminate writing on floppy disk, and other altering of memory;

d) *failure/total inoperability:* this is the most serious category where the product totally fails and cannot be reset to regain operability. Eventually, mechanical damage will occur. No field repair can be accomplished. This creates a need for complete equipment replacement with an urgent redesign to increase its immunity level. Customer service could be interrupted for an indefinite time dependent on the capability of the manufacturer to produce a satisfactory replacement product.

It is the task of the product committees to determine the product degradation criteria for the above conditions.

3.1.3 Product specification details

In addition to specifying the detailed immunity measurement method and the means of determining the degradation of performance acceptable, the product specifications must include other relevant details as outlined below.

3.1.3.1 Test environment

The needs of the test environment must be considered. The physical environment needs to be specified, e.g., temperature or humidity ranges. Also the EM environment must be specified, in particular, the maximum level of ambient signals.

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3.1.3.2 Working conditions of EUT

The working conditions of the EUT must be specified, e.g., the characteristics of the wanted input signal, the modes of operation of the EUT, etc.

3.1.3.3 EM threat

There are many forms of EM disturbances which may cause the EUT to malfunction. The product committee must consider whether the immunity specification should cover all eventualities, i.e., immunity from transmitted radio waves, from conduction of signals, from spikes/dips/outages/distortions on the mains, from electrostatic discharge, from lightning induced surges, etc.

For each potential threat, the mode of coupling must be evaluated so that the appropriate specialized test equipment can be specified together with the covered method of measurement. It will thus be necessary for the product committees to adapt the general measurement principles set out in this clause to their particular product.

The characteristics of the unwanted signal must be specified, e.g., amplitude, modulation, direction, polarization, etc. The frequency range of applicability of each method must be defined, e.g., the useful frequency range of the TEM cell is dependent on its width and this in turn is dependent upon the size of the EUT.

The EUT must be examined to determine whether it is particularly susceptible in any mode of operation or for a particular frequency of unwanted signal.

3.1.3.4 Calibration

The product specification must address calibration needs, either by referring to a basic standard or including the calibration procedure within the product or product family specification. This should include both the periodic calibration of the test equipment used and particularly the means of calibrating said parameters as the amplitude and homogeneity of the unwanted signal as it is used in direct radiation or injection methods.

3.1.3.5 Statistical assessment

The product specification must state the significance of the CISPR limit. In particular, it should address the question of whether the testing should conform to the 80/80 rule of Recommendation 46/1, and if so, which of the sampling methods should be used.

For immunity testing until a performance degradation occurs, compliance with a CISPR limit for immunity may be judged using a suitable sample size such that a portion of the sample may exceed the permissible limit. For immunity testing performed at the immunity limit to determine compliance, e.g. go/no-go testing, without measuring the margin of immunity, statistical techniques may not apply.

3.2 Method of measurement of immunity for conducted signals

The basic method is to inject the unwanted signal into a lead and increase the level until the specified level of degradation is observed or the specified immunity level is reached, whichever is first. The lead may be a signal, a control or mains lead. There are two variants of the method. Current injection is used to assess immunity to common mode (asymmetric) signals, the voltage injection method to assess immunity from differential mode (symmetric) signals. In general current injection is performed as a minimum since that mode is most vulnerable to radiated RF environments.

The general principle of the injection measurement is illustrated in Figure 26. The effects of interference signals induced into a lead of an equipment in an actual situation are simulated by the injection of an unwanted signal through a suitable coupling unit.

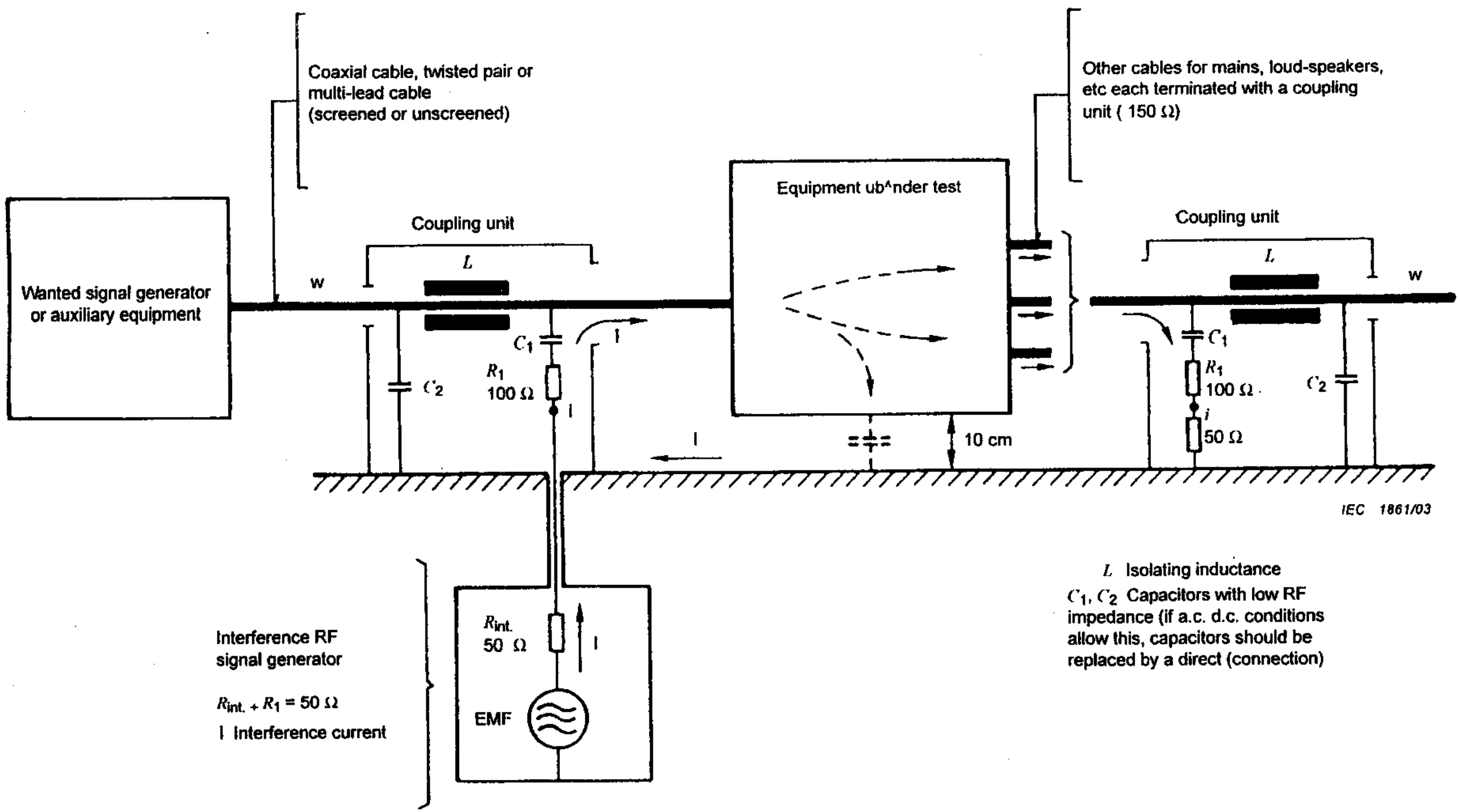

Figure 26 – General principle of the current-injection method (see 3.2)

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In the case of current injection for unshielded leads, the unwanted current is injected in common mode into the conductors. In the case of coaxial or shielded cables the unwanted current is injected into the outer conductor or the shield of the cable also in common mode (see Figure 26). The current flows through the EUT returning to the generator through the ground capacitance in parallel with the load impedances of the other terminals provided by coupling units. Note that in some cases a portion of the common mode signal is converted into differential mode, thus masking the true common-mode response. This may be a combination of common mode currents which affect the RF potential differences at opposite ends of the lead and cause a degradation of the wanted signal to unwanted signal ratios.

In the case of voltage injection, the signal is applied between two wires. Note that at frequencies approaching 100 MHz or greater, conducted immunity injection by both methods is difficult due to the impedances and resonant conditions of the EUT leads and loads.

3.2.1 Coupling units

The coupling units contain RF chokes, capacitors, and resistive networks for the injection of unwanted signals. The impedance of the unwanted signal voltage source and the load impedances are standardized and the coupling units are designed to provide this impedance. They also permit the passage of the wanted test signal, other signals, and mains supply. Construction details and performance checks of coupling units are contained in CISPR 16-1.

3.2.2 Measurement set-up

The arrangement used for conducted immunity measurements must be adequately specified to ensure accuracy and repeatability. Particular items to specify include:

a) height of EUT above a specified ground plane;

b) disposition of excess signal and power leads;

c) length of leads connecting coupling unit to signal and power leads;

d) control of lay-out of all components used, that is EUT, its leads, coupling unit, ground plane, interconnect leads, signal source, etc.;

e) quality of leads, that is, shield connections, transfer impedance, etc.

More details on such specifications follow for the case of measuring the immunity of TV receivers, as an example.

The TV receiver is placed 100 mm above a metallic ground plane of dimensions 2 m by 1 m. The coupling units are inserted into the various leads, respectively. The leads linking the coupling units to the EUT shall be as short as possible, in particular the lead to the antenna input of the EUT shall be not longer than 300 mm.

The mains lead shall be 300 mm long. If longer, it shall be bundled to a length of 300 mm. The mains lead shall be fixed in a well-defined lay-out which shall be recorded in the test report. The distance between the leads and the ground plane shall be not less than 30 mm.

The maximum number of coupling units used in a test shall be six. In the case of EUTs with more than six terminals, coupling units shall be used for at least one of each type of terminals, if present.

NOTE Product committees should include such details in the product specification.

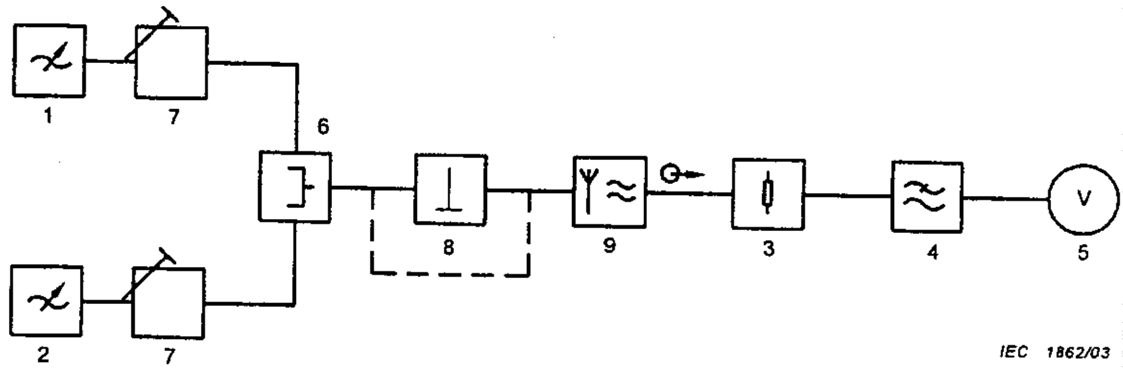
3.2.3 Method of measurement of input immunity

The unwanted signal is applied to the input terminals of EUTs that normally receive radio-frequency signals in that manner. This unwanted signal is mixed with the desired signal. The following subclauses highlight such tests as may apply to sound and television receivers, as examples. Also, see CISPR 13.

3.2.3.1 Measurement of sound receivers

For these measurements the wanted and the unwanted signal frequencies shall be specified in terms of accuracy, e.g., ±1 kHz.

The measuring set-up is shown in Figure 27. The unwanted signal generator (1) and the wanted signal generator (2) are interconnected by means of the coupling network (6). To avoid mutual interference between the two generators, the coupling loss can be increased with the attenuators (7). The output of the coupling network, the source impedance of which shall be specified, shall be matched to the input terminal of the EUT by the network (8). The audio output is measured as specified.

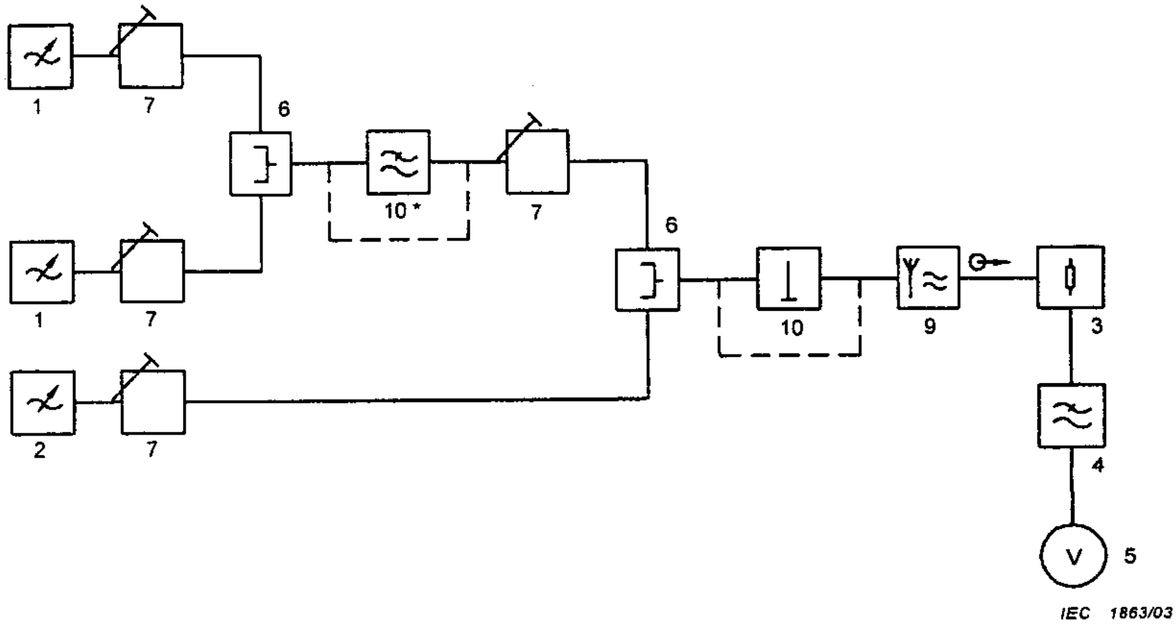


1 Unwanted signal generator G1
2 Wanted signal generator G2
3 Load resistor RL
4 Low-pass filter (see Annex B)
5 Audio-frequency voltmeter (with weighting network according to ITU Recommendation 468)
6 Coupling network
7 Attenuators
8 Matching and/or balancing network
9 Equipment under test (EUT)

Figure 27 – Measuring set-up for input immunity measurement of sound broadcast receivers (see 3.2.3.1)

3.2.3.2 Measurement of television receivers

The measuring set-up is shown in Figure 28. The principle of operation is similar to the measuring set-up of Figure 19 and the remarks in 3.2.3.1 apply. The low-pass filter (10) is added to prevent influence of the measuring results by harmonics of the unwanted signal generators.



1 Unwanted signal generators G1
2 Wanted signal generators G2
3 Load resistor RL
4 Low-pass filter
5 Audio-frequency voltmeter (with weighting network according to CCIR Recommendation 468)
6 Coupling networks
7 Attenuators
8 Matching and/or balancing network
9 Equipment under test (EUT)
10 Low-pass filter*

* To prevent influence of the measuring results by harmonics of the unwanted signal frequency

Figure 28 – Measuring set-up for input immunity measurement of television broadcast receivers (see 3.2.3.2)

3.3 Method of measurement of immunity to radiated electric field interference

The following clauses delineate various methods of measurement of immunity to radiated electric field interference.

3.3.1 Measurements using the TEM mode

A homogeneous, electromagnetic wave under the free space conditions can be simulated by a guided wave of the TEM (transverse electromagnetic) mode travelling between two flat parallel conducting surfaces. In this case the electric field component is perpendicular, and the magnetic field component parallel, to the conductors. TEM devices may be of the open stripline or the closed construction, e.g. TEM or GTEM device. Details of the TEM and stripline devices are given in CISPR 16-1. The description of the GTEM device is under consideration.

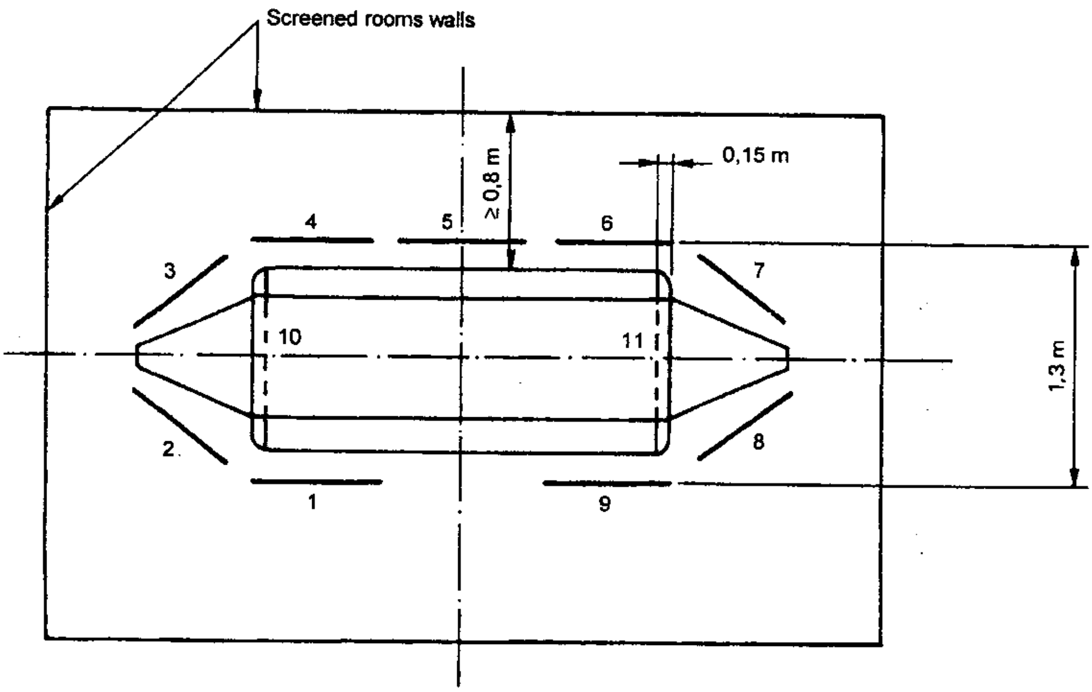
3.3.1.1 Measurement set-up using the open stripline

The open stripline consists of two parallel plates sufficiently spaced apart to accommodate twice the electrical height of an EUT. The metallic structure of the EUT in the vertical plane constitutes the electrical height of the EUT. EUTs whose electrical height is greater than half the parallel plate separation may load the stripline and introduce a significant effect on the applied electric field strength. It should be noted that above the cut-off frequency of the stripline, both perpendicular and horizontal electric field strength components are present.

For the EUTs that meet the above height restriction and for testing generally under 150 MHz, the following arrangement and stripline distances are recommended:

- the base of the stripline shall be placed on non-metallic supports at least 0,8 m from the floor, and the top conductor plate shall be no closer than 0,8 m from the ceiling;
- when used in a room, the stripline shall be spaced at least 0,8 m from its open longitudinal sides to walls or other objects. When used inside a screened room, RF, absorbing material shall be placed in the space between the sides of the stripline and the walls of the screened room. Figure 29 shows the basic arrangements;
- the EUT is placed on a non-metallic support, 100 mm high, in the centre of the stripline (see Figure 30);
- connecting leads to the EUT are inserted through holes in the base conductor plate of the stripline. The lengths of the leads inside the stripline shall be as short as possible and completely surrounded by ferrite rings to attenuate induced currents. The transfer impedance of coaxial cables used shall be not higher than 50 mΩ /m at 30 MHz;
- any balanced-to-unbalanced transformer used shall be connected to the EUT with leads as short as possible;
- terminals of the EUT not used during the measurement shall be terminated with shielded resistors matching the nominal terminal impedance.

If an EUT requires another apparatus in order to function properly that additional apparatus shall be considered as part of the measuring equipment and precautions shall be taken to ensure that the additional apparatus is not exposed to the unwanted signal. These precautions may include additional grounding of coaxial shields, shielding, and inserting of an RF filter on, or the application of ferrite rings to, the connecting cables.



1 to 11: absorbing panels with dimensions of approximately 0,8 m × 0,4 m

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Figure 29 – Example of the arrangement of an open stripline TEM device in combination with absorbing panels inside a screened room with dimensions 3 m × 3,5 m (see 3.3.1.1)

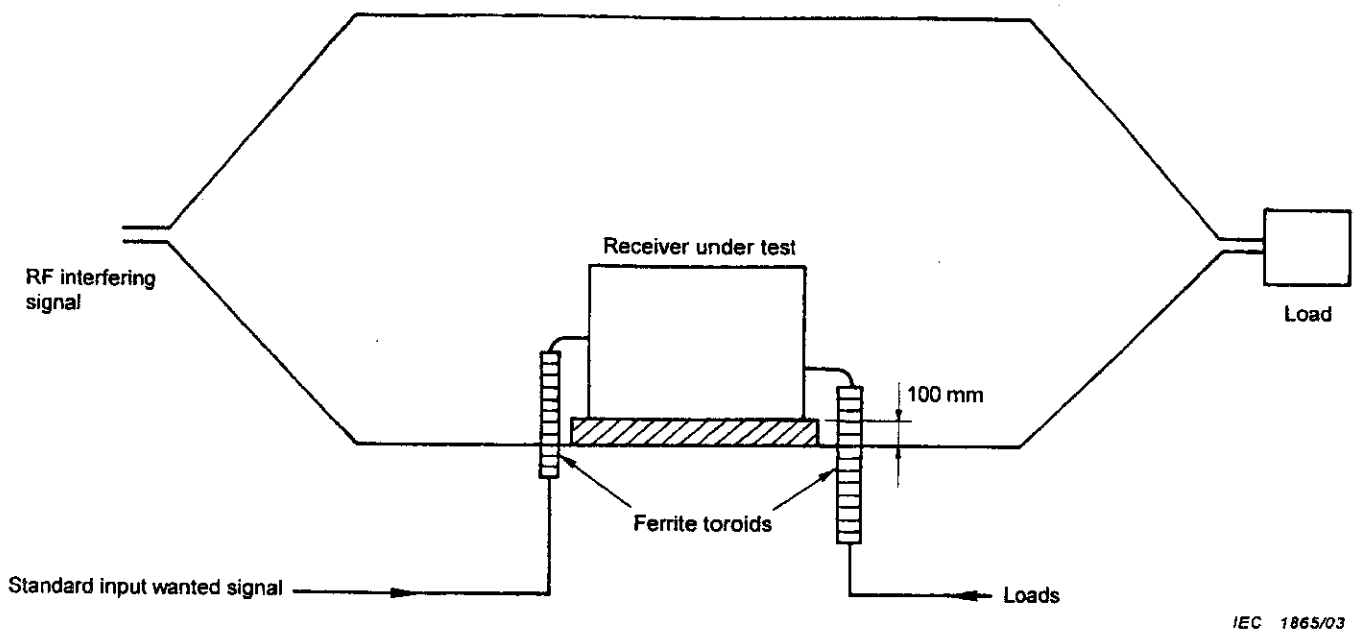

Figure 30 – Measuring set-up for the immunity of broadcast receivers to ambient fields in the frequency range of 0,15 MHz – 150 MHz
(see 3.3.1.1)

3.3.1.1.1 Measurement circuit for receivers

Figure 31 shows the circuit used for measuring the immunity of sound and broadcast receivers. This is an example of the use of the stripline. The wanted test signal is supplied by generator G2 and is connected through a matching network to the input of the EUT.

The unwanted signal is supplied by generator G1 and is connected through switch S1, wide-band amplifier Am, and low-pass filter F to a matching network MN of the stripline. The wide-band amplifier Am may be required to provide the necessary field strength. The stripline is loaded with a terminating impedance.

Care shall be taken with respect to the harmonic level of the RF output of the generator G1 and in particular the output of the wide-band amplifier Am. Harmonics may influence the measurement if they coincide with other responses of the EUT. For the case where the EUT is a TV receiver, such responses from a harmonic may be at the tuned channel or the i.f. channel of the EUT. In some cases provisions shall be made to reduce the harmonic level adequately by inserting a suitable low-pass filter F that can handle the input power from the Am. Specific checks of the suitability of these filters should be made.

The audio output power levels shall be measured as specified in the product requirements.

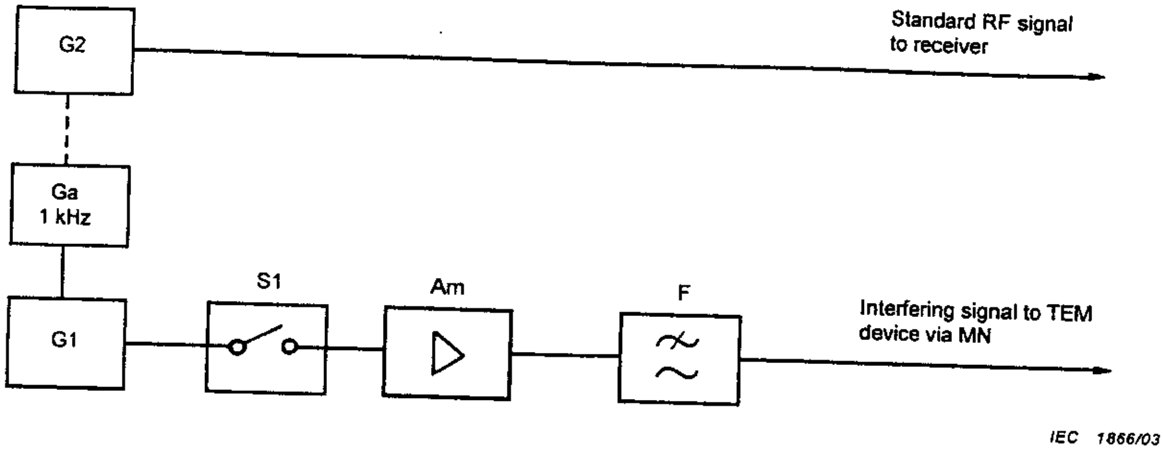

Figure 31 – Measuring circuit for the immunity of sound broadcast receivers to ambient fields (see 3.3.1.1.1)

3.3.1.2 Measurement set-up using a closed TEM device

(Under consideration)

Measurement circuit

(Under consideration)

3.3.2 Measurement using absorber-lined shielded rooms

3.3.2.1 Introduction

Absorber-lined shielded rooms are comprised of a standard six-sided shielded room which has some form of RF-absorbent material applied to the four walls and ceiling. Generally, the shielded room floor is untreated and acts as the reference ground plane for measurements. For field uniformity, the floor of the room may also require the addition of absorber material. The absorber material is generally comprised of carbon-impregnated foam. Other material includes ferrite tiles or combinations of ferrite tiles and carbon-impregnated foam. Both materials dissipate the undesirable energy impinging on its surface in the form of heat. For high power immunity levels, due concern for exceeding the heat dissipation rating of the absorbing material should be given. Special fire-retardant treatments are available for the material.

3.3.2.2 Size

The size of absorber-lined shielded rooms depends on several factors:

a) test area needed for the EUT system;

b) volume necessary to accommodate the transmitting antenna and its required height(s) above the ground plane;

c) size of the absorber material;

d) separation between the antenna and EUT;

e) separation between the EUT and antenna from the closest absorbing material;

f) the dimensional sizes of the chamber required to give the required accuracy and uniformity of immunity field in the test area.

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The size of the absorber-lining material needed is a function of the amount of suppression required of the undesired reflections. Such material which is generally pyramidal in shape for carbon foam is effective when the height of the material is a significant fraction of a wavelength. When this fraction is realized, the absorbing material can attenuate the reflected energy by 20 dB or more. The attenuation values increase considerably when the wavelength is less than that of the height of the pyramidal material. Conversely, the attenuation is degraded to a very low level for carbon-foam absorber material height much less than a wavelength. This latter condition is usually the case for most practical sized absorber material (1 m or less in height below 100 MHz). Use of such absorber-lined rooms is thus seriously restricted at these frequencies or lower.

The response of absorber lined chambers under 100 MHz can be improved by a suitably chosen layer of ferrite tiles and carbon-foam material. In general, the layering consists of ferrites directly mounted on the shielded room walls and ceiling (and perhaps flooring), a layer of dielectric material, the carbon-foam material, and in case of floor applications, an inert fill between the pyramids and a mechanically strong, load-bearing, non-conductive "walk-on" material. The ferrite yields additional reflection reduction below 100 MHz (if properly selected). It should be noted that such ferrites are non-linear suppression materials. The impact on the absorber room reflective properties as a function of frequency should be characterized before using such material, especially above 1 GHz.

3.3.2.3 Transmitting antenna

There are many varieties of transmitting antennas that can be used to reproduce the desired immunity field inside an absorber-lined shielded room. The most critical parameters for such antennas are the ability to dissipate high powers (up to 1 kW) and to have a beamwidth sufficiently wide to illuminate the EUT test area. If polarization information is necessary, linearly polarized antennas should be used. Typical antennas include high power biconical, log periodic arrays and ridged rectangular horns. These antennas should stand well clear of any absorber material. At least a 1 m clearance is suggested.

3.3.2.4 Signal generation

No special signal generator requirements other than adequate suppression of signal generator and power amplifier harmonic and spurious outputs are needed when immunity tests are performed inside an absorber-lined shielded room. The signal sources should be capable of producing both CW and modulated RF carrier levels compatible with the input requirements of the power amplifier used to feed the transmit antenna. Since the EUT may respond to several frequencies over a large bandwidth, it is important that the combination of the signal generator and power amplifier adequately suppress harmonic and spurious outputs. The suppression should be 30 dB or more compared to the desired frequency output and to the immunity limit at these harmonics. A high-power low-pass filter which tracks the output signal may have to be inserted between the amplifier output and the transmitting antenna input.

3.3.2.5 Calibration of generated electric field

The purpose of field calibration is to ensure that the uniformity of the field over the test sample is sufficient to ensure the validity of the tests results.

This standard uses the concept of a "uniform area" which is a hypothetical vertical plane of the field in which variations are acceptably small. This uniform area is 1,5 m × 1,5 m, unless the EUT and its leads can be fully illuminated within a smaller surface. In the test arrangement, the EUT will have its front face coincident with this plane.

Because it is impossible to establish a uniform field close to an earth reference plane, the calibrated area is established at a height no closer than 0,8 m above the earth reference plane and where possible the EUT is located at this height.

In order to establish the severity of the test for EUTs and wires which must be tested close to the earth reference plane or which have larger sides than 1,5 m × 1,5 m, the intensity of the field is also recorded at 0,4 m height and for the full width and height of the EUT, and reported in the test report.

The antennas and cables which have been used to establish the calibrated field shall be used for the testing. Since the same antennas and cables are used, the cable losses and antenna factors of the field-generating antennas are not relevant.

The exact position of the generating antenna shall be recorded. Since even small displacements will significantly affect the field, the identical placement must be used for testing.

NOTE The area of the uniform field should be established at 3 V/m by an unmodulated RF signal. Use of an unmodulated signal assures proper indication of any field intensity measuring device.

3.3.2.6 Performance monitors

Based on the test plan, various sensors should be attached to the EUT to be able to record an analogue or digital signal, which will indicate performance degradation. These sensors and the leads extending outside the absorber-lined shielded room should not affect the performance or immunity of the EUT nor become uncalibrated by the applied immunity field or the presence of the absorber lining. In some cases, the leads from the EUT to the EUT support equipment outside the absorber-lined shielded room can be monitored for performance degradation. The degradation monitors in this case do not have to be immune to the radiated RF energy. They should, however, be immune to any conducted RF currents on the leads outside the room. If visual performance degradation is required, a suitable clear window panel on the shielded room wall or closed circuit television system can be used. The panel area should be converted with an integral shielding material, i.e. wire mesh embedded in glass or conductive transparent material applied to the glass surface. The TV camera should be located embedded inside adjacent pyramidal tips of the carbon-foam material in a position within the room that does not intercept a major reflected EUT signal. Audio degradation can be measured via acoustic couplers or by monitoring the recovered audio modulation of the amplitude modulated RF immunity signal carrier.

3.3.2.7 Immunity measurement set-up

3.3.2.7.1 The EUT is set in the centre of the test zone of the absorber-lined shielded room. A uniform test field for small products, that is, the EUT linear dimensions are less than a wavelength, is obtained when the antenna separation is greater than a wavelength away. The field becomes complex for separations closer than a wavelength. For larger products, i.e., where the EUT dimensions are greater than a wavelength, the antenna should be separated by a distance equal to the largest linear dimension of the EUT in metres squared divided by the wavelength of the immunity signal. If measurements are made at closer separations, the receive antenna will be in the complex near field zone. This complexity must be accounted for in such tests to assure repeatability and the prediction of the far field from such near field data.

3.3.2.7.2 Performance monitors are attached to the EUT as required in the test plan. Field strength sensors, if used, should be placed to monitor or provide field levelling only if the field that is being recreated was so measured at the actual product location when used by a customer. All connections should not be affected by the field or absorber material nor change the performance of the EUT.

3.3.2.7.3 The transmitting antenna should be mounted on an antenna positioner capable of varying the polarization, height and location of the antenna with respect to the ground plane and EUT. Narrow beamwidth antennas should be kept pointed at the EUT as they are raised and lowered.

3.3.2.7.4 Provisions should be made to monitor and record the various performance degradations specified in the test plan. It is strongly suggested where possible that subjective visual or aural monitoring by a test operator be replaced with objective analogue or digital voltage or current EUT response. This electrical monitoring technique minimizes tester errors that result due to the tedious and lengthy test cycle nature of immunity measurements.

3.3.2.8 Immunity test procedure

The test procedures for immunity measurements inside absorber-lined shielded rooms are generally the same as those inside a regular shielded room. Since the interaction of all the reflected signals normally present in an absorber-lined shielded room are much less, absorber-lined room measurements are more accurate and repeatable. In both cases, the test personnel and test instrumentation (amplifier, signal source, etc.) should be located outside the room.

The general test procedure includes the following:

a) establish the calibrated disturbance field strength, polarization and modulation (if any is required);

b) configure and operate the EUT as typically used and orient the EUT to maximize its immunity response;

c) vary the transmitted signal limit at each frequency to measure the level at which degradation occurs or at the specified immunity level, whichever is lower;

d) scan the frequency range contained in the test plan to complete the EUT immunity profile or to determine go/no-go compliance;

e) record the performance degradation and the associated field strength levels as a function of frequency and the other test parameters.

3.3.3 Measurements using an open area test site (OATS)

3.3.3.1 Introduction

Radiated immunity field strength levels are by their very nature significantly higher than radiated emission levels normally regulated by national governments. Typical test levels for much equipment are in excess of 1 V/m. For some EUT systems and large stand-alone electronic equipment, the need to illuminate the entire EUT requires high power, an efficient and wide beamwidth transmitting antenna, and a large test area. The power and antenna requirements are generally independent of the type of test facility used. In some cases the large EUT is not completely functional until all its parts are assembled on site at the user's premises or at a test site that is quite large. One such test site is the same open area test site used for radiated emission measurements. These sites are useful over the full frequency range and have particular applicability above 30 MHz subject to the severe restrictions stated in 3.3.3.3.

3.3.3.2 Measurement site requirements

The open area immunity test site (OAITS) that meets the same requirements for the open area test site (OATS) specified in Clause 5.6 of CISPR 16-1 are physically suitable for immunity tests. Other sites may be used as long as the electric field strength in the volume occupied by the EUT does not vary by more than the specified tolerance. This may require that the transmitting antenna be located on an antenna positioner to change the antenna height and in some cases, polarization, above the ground plane and antenna location. In changing the antenna height, narrow beam-width antennas must be kept pointed towards the EUT. Height change would be used to adjust the addition of the direct signal and then reflected from the ground screen so that a specified uniform field is found in the EUT volume as frequency varies. These requirements need only hold for the frequency range specified in the test plan. Absorber material may be required on the ground plane to meet the field uniformity requirement.

3.3.3.3 Interference to radio services

The potential for causing interference to licensed radio-frequency services in or near the OAITS is generally high due to the very magnitude of the immunity signal. Extreme care should be taken to ensure that the generation of the test field does not adversely affect such RF services, especially in the various safety bands. Fields no higher than needed to measure to the specification limit or to record an EUT performance degradation below that limit should be generated. If generated, they should be applied for very brief time intervals.

There may be certain frequency bands where the interference potential is significantly reduced. For example, ISM band frequencies are likely to be unaffected by such measurements. In some administrations it may be required to secure an experimental radio license from the national authority. The license would detail specific frequencies, time of operation, and length of operation for the immunity RF field strength transmission. Generally, experimental licenses for frequencies used for public radio emergency services, commercial broadcast, government channels, standard time and frequency broadcasts, etc. are not granted. Use of ISM frequencies and other industrial use frequencies are generally more likely to be approved. Note, however, that these approval frequencies may be so spaced apart that the true immunity response will not be completely described.

Under far-fielded conditions the ambient interfacing field E is given by:

$$E = 2 \times 7 \frac{[PG]^{1/2}}{d} = 14 \frac{U}{d}\left[\frac{G}{R}\right]^{1/2}$$

where

U is the input voltage at the tuned radiating antenna with resistance R;

d is the distance between antenna and the location where a sensitive radio receptor may be located;

G is the gain of the antenna with respect to a half-wave dipole.

The factor 2, with an accuracy of 1,5 dB, implies the effect of the total reflection at the ground plane if the height of the transmit antenna is adjusted for maximum field strength. In the case of a vertically polarized transmit antenna, the effective field resulting from the direct and from the reflected field may not be a vertically linearly polarized field.

3.3.3.4 Measurement procedures

3.3.3.4.1 General

Basically, the immunity measurement procedures are the same as those for measurements made using any enclosed test site such as a TEM cell or shielded (absorber-lined or not) room. In the case of the TEM cell the signal is applied between the centre conductor and the outer shell; in the OAITS and other more common shielded enclosures, the immunity signal is fed to a transmitting antenna.

3.3.3.5 Measurement set-up using the open area test site

3.3.3.5.1 General

The power required to establish an immunity field strength is not small. Hence the closer the EUT is to the antenna, the less power required. Most OAITS measurements are performed using EUT/antenna separation distances less than 3 m. For large EUTs, this distance must be increased so that the antenna can illuminate the entire EUT. Power amplifier expense and availability over the frequency range up to 1 000 MHz usually limit large system testing. Component or partial EUT testing is substituted in some cases and judgements made as to the overall large system EUT immunity.

Section 4: Automated measurements

4.1 Automated measurement of emissions

4.1.1 Introduction: Precautions for automating measurements

Much of the tedium of making repeated EMI measurements can be removed by automation. Operator errors in reading and recording measurement values are minimized. By using a computer to collect data, however, new types of errors can be introduced that may have been detected by an operator. Automated testing can lead, in some situations, to greater measurement uncertainty in the collected data than manual measurements performed by a skilled operator. Fundamentally, there is no difference in the accuracy with which an emission value is measured whether manually or under software control. In both cases the measurement uncertainty is based on the accuracy specifications of the equipment used in the test set-up. Difficulties may arise, however, when the current measurement situation is different from the scenarios the software was configured for.

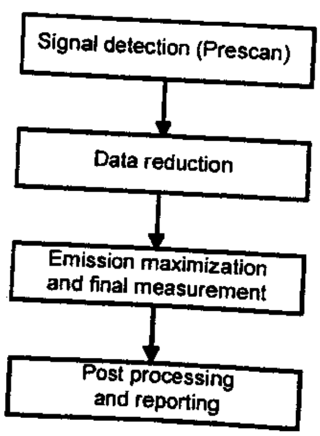
For example, an EUT emission adjacent in frequency to a high level ambient signal may not be measured accurately, if the ambient signal is present during the automated test. A knowledgeable tester, however, is more likely to distinguish between the actual interference and the ambient signal; therefore the method for measuring the EUT emission can be adapted as required. However, valuable test time can be saved by performing ambient scans prior to the actual emission measurement with the EUT turned off to record ambient signals present on the OATS. In this case the software may be able to warn the operator of the potential presence of ambient signals at certain frequencies by applying appropriate signal identification algorithms.

Operator interaction is recommended if the EUT emission is slowly varying, if the EUT emission has a low on-off cycle or when transient ambient signals (e.g. arc welding transients) may occur.

4.1.2 Generic measurement procedure

Signals need to be intercepted by the EMI receiver before they can be maximized and measured. The use of the quasi-peak detector during the emission maximization process for all frequencies in the spectrum of interest leads to excessive test times (see 2.3.5.1). Time-consuming processes like antenna height scans are not required for each emission frequency. They should be limited to frequencies at which the measured peak amplitude of the emission is above or near the emission limit. Therefore, only the emissions at critical frequencies whose amplitudes are close to or exceed the limit will be maximized and measured.

The following generic process will yield a reduction in measurement time:



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4.1.3 Prescan measurements

This initial step in the overall measurement procedure serves multiple purposes. Prescan places the least number of restrictions and requirements upon the test system since its main purpose is to gather a minimal amount of information upon which the parameters of additional testing or scanning will be based. This measurement mode can be used to test a new product, where the familiarity with its emission spectrum is very low. In general, prescan is a data acquisition procedure used to determine where in the frequency range of interest, significant signals are located. Depending on the goal of this measurement, antenna tower and turntable movement may be necessary (for the radiated emission test) as well as improved frequency accuracy (e.g. for further processing on an OATS) and data reduction through amplitude comparison. These factors define the measurement sequence during the execution of prescan. In any case, the results will be stored in a signal list for further processing.

When a prescan measurement is made to quickly obtain information on an EUT's unknown emission spectrum, frequency scanning can be performed by applying the considerations of section 2.3.5.

- Determination of the required measurement time

If the emission spectrum and especially the maximum pulse repetition interval T_p of the EUT is not known, this has to be investigated to assure the measurement time T_m is not shorter than T_p. The intermittent character of the EUT's emission is especially relevant for critical peaks of the emission spectrum. First should be determined at which frequencies the amplitude of the emission is not steady. This can be done by comparing the max-hold with a min-hold or clear/write function of the measuring equipment or software, and observing the emission for a period of 15 s. During this period no change in the set-up should be made (no change of lead in case of conducted emission, no movement of absorbing clamp, no movement of turntable or antenna in case of radiated emission). Signals with e.g. more than 2 dB difference between the max-hold result and min-hold result are marked as intermittent signals. (Care should be taken not to mark noise as intermittent signals.) In case of radiated emissions, the polarisation of the antenna is changed and the measurement is repeated, to reduce the risk that certain intermittent peaks are not found because they remain below noise level. From each intermittent signal the pulse repetition period T_p can be measured by setting the receiver to zero span or using an oscilloscope connected to the IF-output of the measurement receiver. The correct measurement time can also be determined by increasing it until the difference between max-hold and clear/write displays is below e.g. 2 dB. During further measurements (maximization and final measurement) it has to be assured for each part of the frequency range that the measuring time T_m is not smaller than the applicable pulse repetition period T_p.

The **type of measurement** determines the definition of a prescan measurement in the following way.

- **Conducted emissions**: prescan may either be performed on a representative lead, for example lead "L" of the power line or on each lead using peak detection and the fastest scan time possible. If multiple leads are measured, a "maximum hold" function should be used to retain the highest emissions found during the measurement.
- For measurements **using the absorbing clamp**, prescan may be performed with the absorbing clamp close to the EUT.

  For conducted emissions or emissions measured with the absorbing clamp, two limits, for quasi-peak and average detector, may be called out. In this case, prescan can include a measurement with the average detector if the peak data exceeds the average limit, before data reduction is applied. Otherwise narrowband emissions which exceed the average limit, may be hidden by broadband emission which are below the Quasi-Peak limit; therefore a non-compliance situation cannot be detected. It should be noted that narrowband responses do not necessarily correspond with broadband emission peaks.
- For **radiated emissions** in the frequency range from 9 kHz to 30 MHz both the loop antenna and the EUT need to be rotated to find the maximum field strength while the receiver is scanning the emission spectrum.

In the frequency range from 30 MHz to 1 000 MHz the antenna height may be preset to fixed heights given in Table 2, based on measurement distance, frequency range and polarization. The necessary prescan measurements must be made for a sufficient number of EUT azimuths. For quick overview measurements this will yield an indication of the radiated emission amplitudes as a starting point for final maximization. If a more detailed determination of the worst case antenna height, polarization and EUT azimuth is desired, the applicable standard should be used to determine the appropriate maximization procedure.

In the frequency range above 1 GHz the antenna needs to be positioned in horizontal and vertical polarization and the EUT rotated to find the maximum field strength while the emission spectrum is scanned. If the EUT surface is wider than the receiving antenna beam, the antenna needs to be moved horizontally and vertically along the vertical plane parallel to the EUT in order to cover the EUT surface (see 2.6.3.4.1).

Table 2 – Recommended antenna heights to guarantee signal interception (for prescan) in the frequency range 30 MHz to 1 000 MHz

Measurement distance m	Polarization	Frequency range MHz	Recommended antenna heights for each frequency range m
3	h	30 – 100	2,5
		100 – 250	1/ 2
		250 – 1 000	1/ 1,5
	v	30 – 100	1
		100 – 250	1/ 2
		250 – 1 000	1/ 1,5/ 2
10	h	30 – 100	4
		100 – 200	2,5/ 4
		200 – 400	1,5/ 2,5/4
		400 – 1 000	1/1,5/2,5
	v	30 – 200	1
		200 – 300	1/ 3,5
		300 – 600	1/ 2/ 3,5
		600 – 1 000	1/ 1,5/ 2/ 3,5
30	h	30 – 300	4
		300 – 500	2,5/ 4
		500 – 1 000	1,5/ 2,5/ 4
	v	30 – 500	1
		500 – 800	1/ 3,5
		800 – 1 000	1/ 2,5/ 3,5

NOTE 1 The recommended antenna heights have been derived for source phase centre heights of between 0,8 m and 2,0 m for maximum errors of 3 dB (which is acceptable for a prescan only). If the range of phase centre heights is reduced, the number of receive antenna heights may be reduced. If lobing occurs, e.g. in the upper frequency ranges, more antenna heights may be needed.

NOTE 2 For very large EUTs, e.g. telecom systems, the receiving antenna may need to be positioned in several vertical and horizontal positions, depending on the antenna beam width.

4.1.4 Data reduction

The second step in the overall measurement procedure is used to reduce the number of signals collected during prescan and thus aimed at further reduction of the overall measurement time. These processes can accomplish different tasks, e.g., determination of significant signals in the spectrum, discrimination between ambient or auxiliary equipment signals and EUT emissions, comparison of signals to limit lines, or data reduction based on user-definable rules. Another example of data-reduction methods involving the sequential use of different detectors and amplitude versus limit comparisons is given by the decision tree in Annex D of this standard. Data reduction may be performed fully automated or interactively, involving software tools or manual operator interaction. It need not be a separate section of the automated test, i.e. it may be part of a prescan.

In certain frequency ranges, especially the FM band, an acoustic ambient discrimination is very effective. This requires signals to be demodulated to be able to listen to their modulation content. If an output list of prescan contains a large number of signals and acoustic discrimination is needed, it can be a rather lengthy process. However, if the frequency ranges for tuning and listening can be specified, only signals within these ranges will be demodulated. The results of the data reduction process are stored in a separate signal list for further processing.

4.1.5 Emission maximization and final measurement

During the final test the emissions are maximized to determine their highest level. After the maximization of the signals, the emission amplitude is measured using quasi-peak detection and/or average detection, allowing for the appropriate measurement time (at least 15 s if the reading shows fluctuations close to the limit).

The **type of the measurement** defines the maximization process yielding the highest signal amplitudes:

- for **conducted emission** measurements: maximization by comparison of the emission amplitudes on the different leads of the EUT power cord and retention of the maximum levels;
- for measurements with the **absorbing clamp**: amplitude maximization by variation of the clamp position along the leads;
- for **radiated emission** measurements:

  in the frequency range from 9 kHz to 30 MHz:
  maximization of the indicated level by variation of the EUT azimuth and the loop antenna azimuth;

  in the frequency range from 30 MHz to 1 000 MHz:
  maximization of the indicated level by variation of height and polarization of the measurement antenna as well as variation of the EUT azimuth;

  in the frequency range above 1 GHz:
  maximization of the indicated level by variation of the antenna polarization and variation of the EUT azimuth and, if the EUT surface is wider than the antenna beam, by moving the antenna along the EUT surface.

Before the actual maximization sequence can be executed, the worst-case EUT set-up has to be determined to ensure the detection of maximum emission amplitudes. The process of finding the EUT and cable configuration that yields the worst case emissions is primarily a manual operation. This can be done using a scanning receiver with a graphical display of the emission spectrum and signal max hold capability for observing the changes in amplitudes as cable and equipment layouts are manipulated. The automated final measurement of emissions should begin after the worst case EUT configuration has been set up.

The measurement of a particular radiated emission includes a maximization process involving the rotation of the EUT, scanning the receive antenna over a height range, and changing antenna polarization. This time-consuming search process can be effectively automated, but it must be recognized that a variety of search strategies may be used which can lead to different results. In case of previous knowledge of the EUT's radiation characteristics, a maximization sequence should be chosen which allows the determination of the worst-case amplitude within the search ranges of the antenna mast and the turntable. For instance, if the EUT emits highly directive signals in the horizontal plane, e.g., due to slots in the case, the turntable should be rotated continuously while taking data with the receiver. A table movement in discrete steps, on the other hand, may not allow the detection of the maximum amplitude or may cause the signal to be missed completely if the chosen angular increments of the positions are too far apart.

One search strategy might be to rotate the turntable 360° while leaving the antenna at a fixed height to find the angle for maximum emission amplitude. Next, the turntable is rotated back over the full range after the antenna polarization was changed (e.g., from horizontal to vertical). During this process test data is taken continuously with the receiver and at the end of the second table scan the highest amplitudes, based on turntable angle and antenna polarization, are determined. Then, the worst case turntable position and antenna polarization are selected and the antenna is scanned over the required height range to find the position yielding the maximum amplitude. At this point the emission level is either recorded using the receiver's quasi-peak detector after returning to the maximum emission height, or finer search continues with incremental rotation of the turntable and following incremental height search, to find the maximum emission amplitude at the given frequency with greater precision. Again, it is important to have some understanding of the radiation pattern of the EUT in order to set up the software for an optimum search strategy that finds the maximum of the EUT emission in the shortest time. Variability is introduced into the test result when the final measurement is performed on the slope of the radiation pattern rather than on its peak.

4.1.6 Post processing and reporting

The last part of the test procedure addresses documentation requirements. The functionality for defining sorting and comparison routines which then can be automatically or interactively applied to signal lists supports a user in compiling the necessary reports and documentation. The corrected peak, quasi-peak or average signal amplitudes should be available as sorting or selection criteria. The results of these processes are stored in separate output lists or can be combined in a single list and are available for documentation or further processing.

Results shall be available in tabular and graphics format for use in a test report. Furthermore, information about the test system itself, e.g. transducers used, measuring instrumentation, and documentation of the EUT set-up as required by the product standard should also be part of the test report.

Section 5: Factors influencing measurement accuracy

5.1 Factors influencing measurement accuracy

Measurement errors can occur due to the following:

- mismatch (see 2.2.1);
- insufficient signal-to-noise ratio;
- meter and display errors;
- overload and intermodulation effects of the measuring receiver;
- calibration accuracy of ancillary equipment;
- presence of extraneous interference.

During measurements in the presence of extraneous interference, ranges of higher sensitivity, which do not comply with the requirements of CISPR 16-1 of this standard with respect to the standing wave ratio and overloading characteristics and which should be marked accordingly, shall not be used. If measurements have to be carried out in these ranges, besides checking for overloading, the extraneous interference voltage superimposed by the noise of the measurement receiver shall be measured when the test object is switched off.

During measurements at the place of installation, it is recommended to monitor the AF signal of the radio interference measurement receiver in order to distinguish between extraneous interferences and the signal to be measured.

5.1.1 Accuracy of measurements

The error for sinusoidal voltages at the receiver input shall not exceed ± 2 dB. Additional errors are introduced by ancillary equipment. (Methods to analyze overall measurement uncertainty are under consideration.)

5.1.2 Avoidance of extraneous signals and effects

a) Maximum permitted level of extraneous signals (see 2.3.1). The measurement error due to extraneous interference shall be less than 1 dB. This requirement has been fulfilled if extraneous interference, measured when the test object is switched off, is 20 dB below the radio interference voltage to be measured, or is not measurable.

b) Filtering and shielding measures. In order to avoid extraneous interference, radio interference voltage measurements can be carried out in screened rooms and with an additional mains decoupling filter (if necessary with an isolating transformer) (see also 2.3.1). If the extraneous interference (also noise of the measurement received) cannot be reduced to the required signal-to-noise ratio of 20 dB, the extent of the extraneous interference voltages shall be recorded in the testing report.

c) Overload and intermodulation check. In the case of radio interference caused by pulses, measurement errors may arise due to overload of the measurement device. Overloading is made evident by an indication of the measured variable which is lower than the true value.

Overloading is insignificant if the display drops by less than 1 dB when the input voltage attenuator is reduced by a minimum of 10 dB and if the complete i.f. gain is reduced by the same amount after the i.f. amplifier. If the reading drops by more than 1 dB, intermodulation has occurred or there was an insufficient signal-to-noise ratio.

This check is not relevant for interference measurement receivers with automatically controlled overload protection.

Annex A
(informative)

Guidelines to connection of electrical equipment to the artificial mains network
(see 2.2)

A.1 Introduction

This annex is intended to give general guidance in the techniques which can be used to assess the disturbance generated by certain electrical equipment in the frequency range 9 kHz to 30 MHz. It provides information on methods of connection of such equipment to the artificial mains network for the measurement of terminal voltages. A table is provided giving a general presentation of various cases encountered in practice enabling, for such cases, a suitable technique to be selected.

The cases described below in A.2 identify propagation of the EUT disturbance either:

a) by **conduction** along the connected mains leads (designated with E_1 and I_1 in the equivalent circuit diagrams), or

b) by **radiation** and coupled to the connected mains lead (designated with E_2 and I_2 in the equivalent circuit diagrams).

Whether conducted or radiated disturbance dominates is partly dependent on the arrangement of the EUT with respect to the ground reference (including the type of connection to the reference ground) and of the type of connection from the EUT to the artificial mains network (shielded or non-shielded cable).

A.2 Classification of the possible cases

A.2.1 Well-shielded but poorly filtered EUT (Figures A.1 and A.2)

In this case, the conducted disturbance component represented by the current I_1 dominates. The disturbance current I_1 is fed from the EUT to the artificial mains network Z. Consequently, the voltage U_1 increases when capacitance C_1 between the EUT shield and the ground reference increases (see Figure A.1). The voltage U_1 is maximized ($U_1 = ZI_1 = E_1$) when the impedance of the current return path is minimized by short-circuiting C_1 either directly or by using shielded cables to supply the EUT (see Figure A.2). (Also, see the discussion in Clause A.3.)

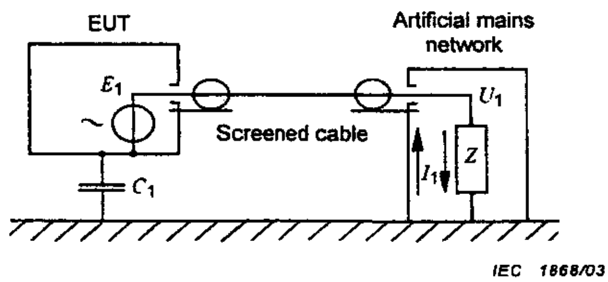


Figure A.1 (see A.2.1)

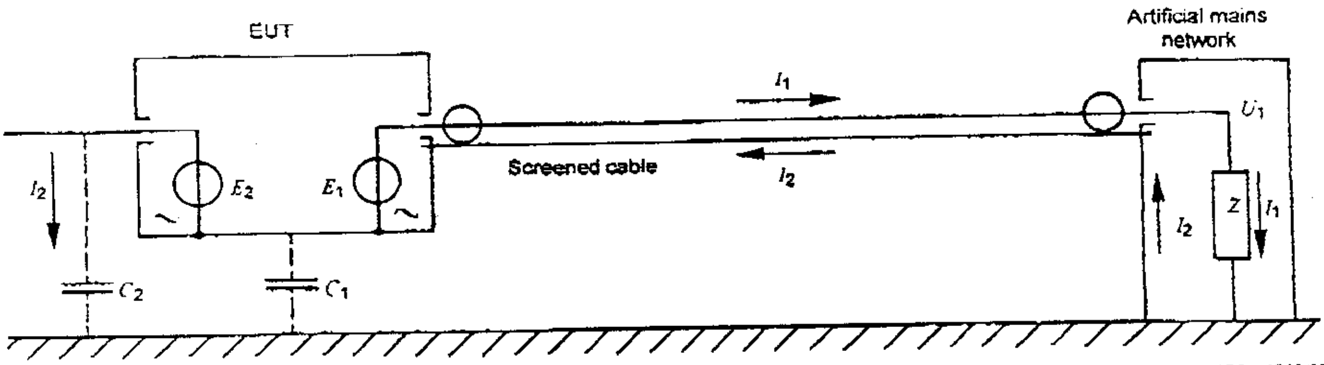


Figure A.2 (see A.2.1)

A.2.2 Well-filtered but incompletely shielded EUT (Figures A.3 and A.4)

In this case, the disturbance current fed to the mains is reduced practically to zero, and the voltage across the artificial mains network may be dominated by undesirable radiation either from gaps in an incomplete shield or from a protruding conductor acting as an antenna. Such leakage can be represented schematically by an external capacitor C_2 connected between an internal disturbance source of e.m.f. E_2 and ground reference. This capacitance C_2 passes a current I_2. Part of the current I_2 which flows through C_2 to the ground reference returns via C_1 and a part of I_2 returns via the artificial mains network. If the supply leads are unshielded (Figure A.3) and the impedance of C_1 is large compared with the artificial mains impedance Z ($ZC_1\,\omega << 1$), then I'_2 is nearly equal to I_2 and the voltage U_2 is nearly equal to I_2Z ($U_2 = ZI_2$).

If C_1 is increased, Z is shunted and U_2 will decrease. At the limit, when C_1 is short-circuited by supplying the EUT through shielded cables (Figure A.4), so that no part of I_2 flows through Z, then U_2 will be zero.

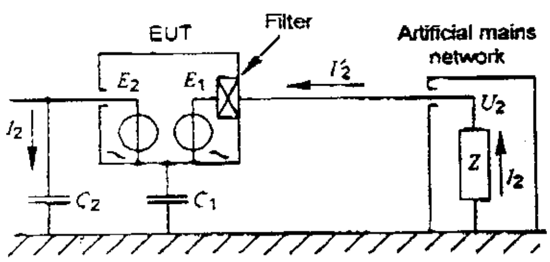


Figure A.3 (see A.2.2)

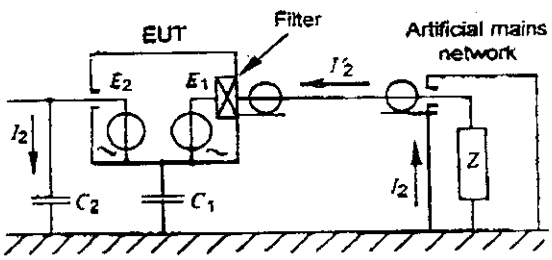


Figure A.4 (see A.2.2)

A.2.3 Practical general case

Most usually in practices, neither the shielded nor the filtering are perfect; the two preceding effects then occur simultaneously and they are additive. In such conditions, the three following cases may be encountered.

A.2.3.1 Supply through shielded conductors (Figure A.5)

The current I_1 caused by leakage due to radiation flows in a circuit closed through ground and the external surfaces of the screening of the artificial mains network and of the supply conductors; it has no effect on Z.

The voltage U_1, which may be measured across Z, is solely due to the current I_1 injected into the supply conductors and returning through the internal surfaces of the screening of the artificial mains network and these conductors. The voltage U_1 is then maximum:

$$U_1 = ZI_1 \approx E_1$$

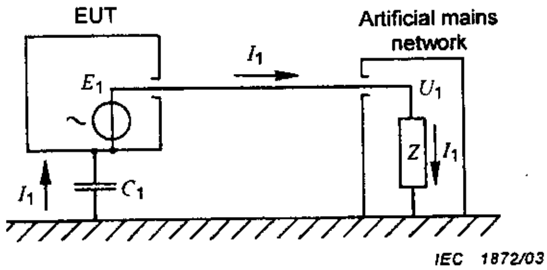


Figure A.5 (see A.2.3.1)

A.2.3.2 Supply through unshielded but filtered conductors (Figure A.6)

If a highly efficient low-pass filter is connected to the input of the EUT, with its screening directly connected to the screening of the EUT, the current I_1 fed by source E_1 to the mains conductors will be stopped by the filter.

As in the case represented in Figure A.6, the current I_2 due to the radiation returns through Z and the conductors (if $ZC_1\ \omega$ << 1); the voltage U_2 measured across Z is then produced solely by the radiation.

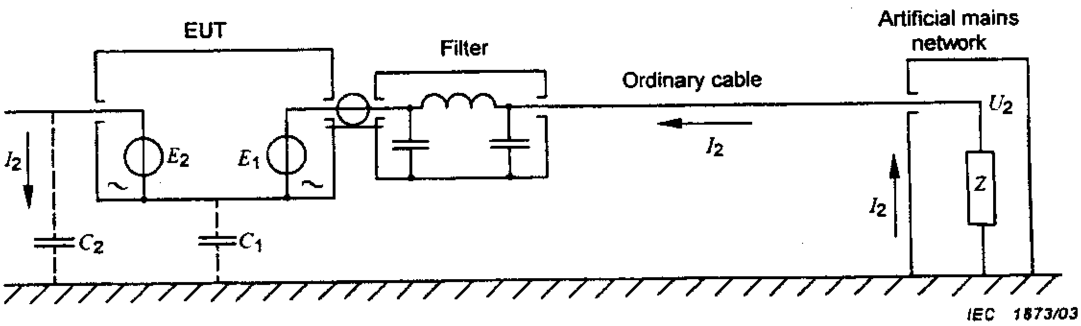


Figure A.6 (see A.2.3.2)

A.2.3.3 Supply through ordinary conductors (Figure A.7)

Should the filter in Figure A.6 be removed, the current I_1 from source E_1 reappears on the conductors (Figure A.7). In comparison to Figure A.5 (with the maximum possible value of I_1 for the supply of a non-filtered EUT through shielded conductors) the value of I_1 in Figure A.7 (supply of a non-filtered EUT through ordinary i.e. unshielded conductors) is, if $ZC_1\ \omega$ << 1, reduced to a minimum value in the ratio of I_1 (EUT unshielded) / I_1 (EUT shielded) = $ZC_1\ \omega$ referred to its minimum value (Figure A.2). The current I_2 is the same as in the previous cases, but as the conductors are not shielded, it passes also through Z and the mains conductors.

The voltage U across the artificial mains network results then from the superposition of currents I_1 and I_2. When electromotive forces E_1 and E_2 are themselves produced by a common internal source, these currents are synchronous and the voltage U depends not only on their values but also on their phases. For certain frequencies, it may occur that currents I_1

and I_2 are in opposition and if they are also of approximately the same magnitude, the voltage U may become very small even if I_1 and I_2 are individually quite large. Moreover, if the frequency of the source varies, the phase opposition may not remain constant and voltage U may show rapid and considerable variations.

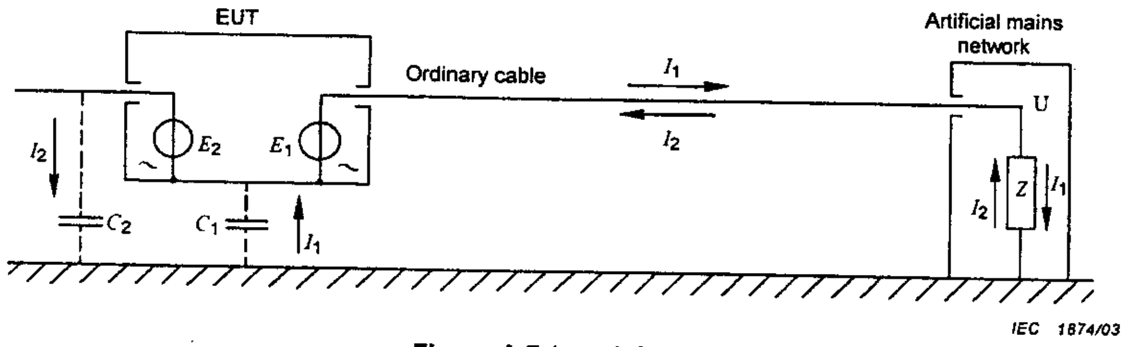


Figure A.7 (see A.2.3.3)

A.3 Method of grounding

In the foregoing, the connection to ground of the EUT was assumed to be made through connection of shielding of the supply conductors to the ground reference.

This is the only correct solution in order to obtain a grounding allowing a clear distinction between the two kinds of currents I_1 and I_2, as indicated above. It may be applied, without exception to all frequencies.

For frequencies below 1,6 MHz practically the same result may be achieved by grounding through a straight lead of small length (1 m maximum), running parallel to the mains lead and not more than 10 cm distant from it.

For frequencies above a few MHz, this simplified solution should only be used with care, especially at the higher frequencies. It is then strongly recommended that screened conductors be used in all cases. At the higher frequencies, it may be necessary to take into account the characteristic impedance of the conductor.

A.4 Conditions of grounding

A.4.1 General

A.4.1.1 General rules

It appears from the considerations discussed above that the behaviour of the measuring circuit for the voltage across the artificial mains network and, hence, the result of these measurements, is largely dependent on how the frame of the EUT being tested is connected to ground. It is therefore essential to specify these conditions closely.

Essentially, the principal effect of grounding is to separate the two currents I_1 and I_2 and possibly to cause opposing variations of their respective actions on the measuring apparatus (which measures voltage U across Z). In the limiting case of a direct connection from the body of the EUT to ground, which short-circuits C_1, the values of current I_1 and thus of voltage $U_1 = ZI_1 \approx E_1$, are maximum; on the contrary, the current I_2 due to radiation passes entirely through this short circuit and the corresponding voltage U_2 is reduced to zero.

From these remarks, the following general rules are drawn.

Direct grounding should always be used when testing:

a) a non-radiating EUT (e.g. a motor) as, in such a case, the measurement yields the maximum value of the disturbance voltage which may be met in practice;

b) a poorly filtered radiating EUT when, without troubling to measure the radiation, it is wished to measure solely the disturbance voltage due to direct injection into the supply conductors:

   1) either for assessing the efficiency of the filter (for instance, for the time base circuits of television receivers);

   2) or for assessing, in the laboratory, the actual disturbance produced by an apparatus whose radiation in normal operation will be suppressed by shielding (e.g. a transformer for the ignition system of fuel for boilers).

A.4.1.2 Direct grounding

Direct grounding should not be used when testing item b)1) of A.4.1.1 nor for a very well-filtered EUT which generates considerable radiation (for example, ozonizer, medical apparatus with damped oscillations, arc welders, etc.). In all these cases, the voltage across the artificial mains network becomes very small with direct grounding, while without such grounding the voltage may be quite large or unsteady. The measurement may then be meaningless and it may become necessary to make the grounding through a specified impedance in order to simulate the actual impedance of the safety ground (protective earth) conductor, e.g. by a protective ground choke which additionally provides some RF isolation from the "polluted" and therefore "poor" protective earth ground (see lower part of Table A.2).

NOTE The impedance of such an "electrical long" conductor is, in case of an EUT of safety protection Class I, normally equal to the mains simulation impedance specified as termination for the mains terminals of the EUT provided by the artificial mains network (constituted by the network of 50 µH + 1 Ω which, due to thermal problems in case of high current loads, may be reduced to a network of 50 µH).

A.4.1.3 No grounding

Without any grounding, the voltage across the artificial mains network results from the addition of both currents I_1 and I_2. A measurement can only be obtained when one of these currents is reduced to zero, either with a very well-screened shielded but poorly filtered EUT (e.g. a motor) or with a very well-filtered but radiating EUT (e.g. a television receiver, an ozonizer, etc.).

NOTE If in case of an EUT of safety protection Class I for the purpose of analysis of I_2, for the reduction of I_1 the impedance according to the note under A.4.1.2 is not sufficient, a high impedance RF choke (1,6 mH) may be inserted into the ground conductor path.

The measurement usually yields only the value of the total disturbance, without allowing any discrimination, the results being only valid for the conditions used during the test. Such conditions should then be very well defined, namely the values of the capacitance to the ground plane of the various elements of the EUT (for instance, the capacitance of the transmission line from the aerial in the case of a television receiver). Moreover, a single measurement for one arbitrary frequency has no significance if, for this frequency, currents I_1 and I_2 are in opposition. As a matter of principle, then, it is necessary to make measurements at a number of frequencies.

A.4.2 Classification of typical testing conditions

Tables A.1 and A.2 summarize the various testing conditions and the types of EUTs for which they are suitable. The tables also give the meaning of the measurement, that is, the physical quantity which corresponds to the voltage U measured across the artificial mains network Z and also the precautions to be taken when making the measurement.

Table A.1 (see A.4.2)

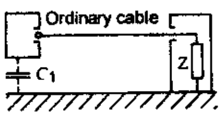
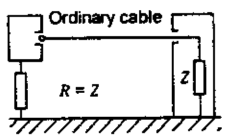
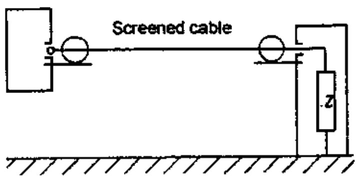
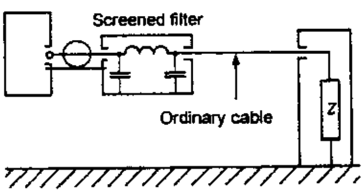
<table>
<tr><th rowspan="3">Method of connection</th><th colspan="4">Types of apparatus</th><th rowspan="3">Quantity measured</th><th rowspan="3">Details of the measurement</th></tr>
<tr><th rowspan="2">Examples</th><th colspan="3">Essential characteristics</th></tr>
<tr><th>Earthing</th><th>Radiation</th><th>Filtering</th></tr>
<tr><td rowspan="5">
</td><td>Motors
Electro-domestic appliances</td><td rowspan="4">Without</td><td>Weak</td><td>Moderate</td><td>Actual interference (reduced) solely due to injected current C_1</td><td>The interference depends on C_1</td></tr>
<tr><td rowspan="4">Ozonizers
Medical apparatus
Arc-welding
Television receivers (time-base)</td><td rowspan="4">Strong</td><td>Very good</td><td>Actual interference solely due to radiation current I_2</td><td rowspan="2">It is necessary to state accurately the position of the appliance with regard to earth or to quote the value of C_1</td></tr>
<tr><td rowspan="2">Moderate</td><td>Total overall interference resulting from the superposition of the two preceding effects (I_1 and I_2)</td></tr>
<tr><td>These two effects (I_1 and I_2) may be in phase opposition at certain frequencies</td><td>Measurement should be repeated, the frequency being varied</td></tr>
<tr><td>With</td><td>Very good</td><td>Actual interference produced with an earth connection of usual length</td><td>The position of the appliance with regard to earth should be specified in order that $RC_{1\infty} < 1$</td></tr>
</table>

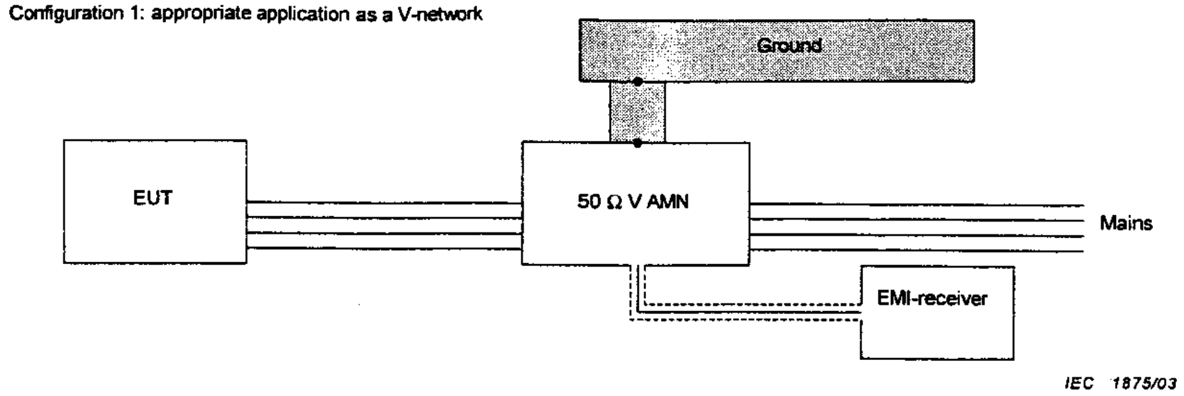
Table A.2 (see A.4.2)

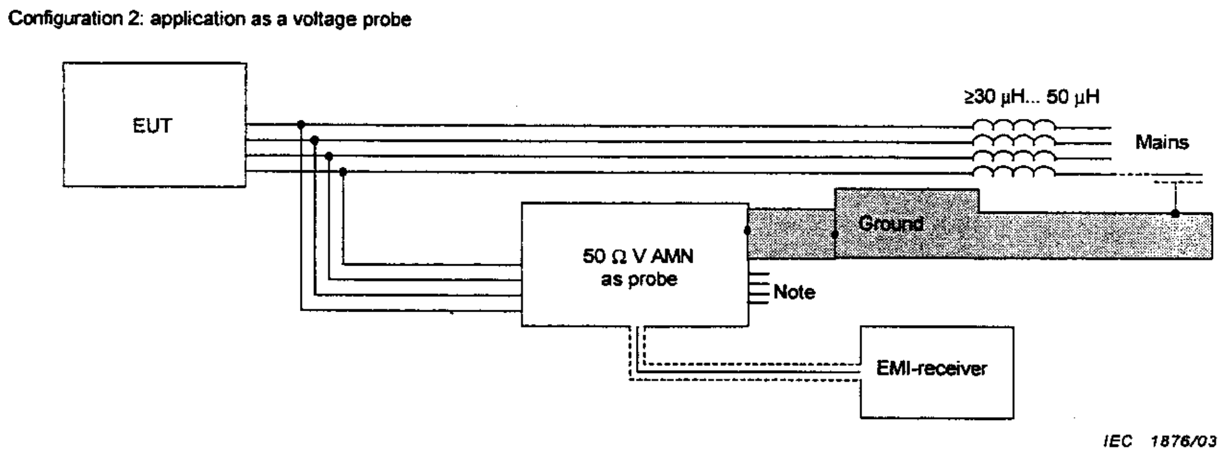
<table>
<tr><th>Method of connection</th><th>Types of apparatus</th><th>Quantity measured</th><th>Examples</th><th>Details of the measurement</th></tr>
<tr><td rowspan="3">
</td><td>Non-radiating appliances provided with an earth terminal</td><td>Maximum actual interference as C_1 is short-circuited</td><td>All motors provided with an earth terminal</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">Radiating appliances when it is desired to measure only the interference caused by current feed to mains</td><td>Check on the efficacy of the screening</td><td>Television receivers
Medical apparatus
Ozonizers
Arc-welding</td></tr>
<tr><td>Actual interference caused by an appliance which, in normal use, must be carefully screened</td><td>Transformer for the ignition system of oil burners
Part of a screened assembly separately tested</td></tr>
<tr><td rowspan="2">
</td><td rowspan="2">Poorly filtered appliances when it is desired to measure only the interference caused by radiation</td><td>Check on the efficacy of the screening</td><td>Television receivers. High-frequency industrial apparatus</td><td rowspan="2">The position of the appliance with regard to earth should be specified in order that $ZC_{1\infty} < 1$</td></tr>
<tr><td>Actual interference caused by an appliance which, in normal use, must be provided with a good filter</td><td>Fluorescent lighting</td></tr>
</table>

A.5 Connection of the AMN as a voltage probe

Conducted emission measurements of EUTs with high operational currents may cause difficulties. AMNs for the frequency range 9 kHz to 150 kHz (30 MHz) are available to approximately 25 A nominal current. AMNs for the frequency range 150 kHz to 30 MHz (50 µH parallel to 50 Ω) are available to approximately 200 A.

EUTs with higher current rating may be tested using the AMN as a voltage probe. This alternative solution is also helpful for *in situ* measurement, if referred to in the applicable product standard.





NOTE Exposed pins must be made safe.

Figure A.8 – AMN configurations (see A.5)

Annex B
(informative)

Use of spectrum analyzers and scanning receivers
(see 2.3)

B.1 Introduction

When using spectrum analyzers and scanning measuring sets, the following characteristics should be taken into account:

B.2 Overload

Most spectrum analyzers have no RF preselection in the frequency range up to 2 000 MHz; that is, the input signal is directly fed to a broadband mixer. To avoid overload, to prevent damage and to operate a spectrum analyzer linearly, the signal amplitude at the mixer should typically be less than 150 mV peak. RF attenuation or additional RF preselection may be required to reduce the input signal to this level.

B.3 Linearity test

Linearity can be measured by measuring the level of the specific signal under investigation and repeating this measurement after an X dB attenuator has been inserted at the input of the measuring set or, if used, the preamplifier ($X \geq 6$ dB). The new reading of the measuring set display should differ by X dB not more than ± 0,5 dB from the first reading when the measuring system is linear.

B.4 Selectivity

The spectrum analyzer and scanning measuring set must have the bandwidth specified in CISPR 16-1 to correctly measure broadband and impulsive signals and narrowband disturbance with several spectrum components within the standardized bandwidth.

B.5 Normal response to pulses

The response of a spectrum analyzer and scanning measuring set with quasi-peak detection can be verified with the calibration test pulses specified in CISPR 16-1. The large peak voltage of the calibration test pulses typically requires an insertion of RF attenuation of 40 dB or more to satisfy the linearity requirements. This decreases the sensitivity and makes the measurement of low repetition rate and isolated calibration test pulses impossible for bands B, C and D. If a preselecting filter is used ahead of the measuring set, then the RF attenuation can be decreased. The filter limits the spectrum width of the calibration test pulse as seen by the mixer.

B.6 Peak detection

The normal (peak) detection mode of spectrum analyzers provides a display indication which, in principal, is never less than the quasi-peak indication. It is convenient to measure emissions using peak-detection because it allows faster frequency scans than quasi-peak detection. Then those signals which are close to the emission limits need to be remeasured using quasi-peak detection to record quasi-peak amplitudes.

B.7 Frequency scan rate

The scan rate of a spectrum analyzer or a scanning measuring set should be adjusted for the CISPR frequency band and the detection mode used. The minimum sweep time/frequency or the fastest scan rate is listed in the following table:

Band	Peak-detection	Quasi-peak detection
A	100 ms/kHz	20 s/kHz
B	100 ms/MHz	200 s/MHz
C and D	1 ms/MHz	20 s/MHz

For a spectrum analyzer or scanning measuring set used in a fixed tuned non-scanning mode, the display sweep time may be adjusted independently of the detection mode and according to the needs for observing the behaviour of the emission. If the level of disturbance is not steady, the reading on the measuring set must be observed for at least 15 s to determine the maximum (see 2.3.4.1).

B.8 Signal interception

The spectrum of intermittent emissions may be captured with peak-detection and digital display storage if provided. Multiple, fast frequency scans reduce the time to intercept an emission compared to a single, slow frequency scan. The starting time of the scans should be varied to avoid any synchronism with the emission and thereby hiding it. The total observation time for a given frequency range must be longer than the time between the emissions. Depending upon the kind of disturbance being measured, the peak detection measurements can replace all or part of the measurements needed using quasi-peak detection. Re-tests using a quasi-peak detector should then be made at frequencies where emission maxima have been found.

B.9 Average detection

Average detection with a spectrum analyzer is obtained by reducing the video bandwidth until no further smoothing of the displayed signal is observed. The sweep time must be increased with reductions in video bandwidth to maintain amplitude calibration. For such measurements, the measuring set shall be used in the linear mode of the detector. After linear detection is made, the signal may be processed logarithmically for display, in which case the value is corrected even though it is the logarithm of the linearly detected signal.

A logarithmic amplitude display mode may be used, for example, to distinguish more easily between narrowband and broadband signals. The displayed value is the average of the logarithmically distorted IF signal envelope. It results in a larger attenuation of broadband signals than in the linear detection mode without affecting the display of narrowband signals. Video filtering in log-mode is, therefore, especially useful for estimating the narrowband component in a spectrum containing both.

B.10 Sensitivity

Sensitivity can be increased with low noise RF pre-amplification ahead of the spectrum analyzer. The input signal level to the amplifier should be adjustable with an attenuator to test the linearity of the overall system for the signal under examination.

The sensitivity to extremely broadband emissions which require large RF attenuation for system linearity is increased with RF pre-selecting filters ahead of the spectrum analyzer. The filters reduce the peak amplitude of the broadband emissions and less RF attenuation can be used. Such filters may also be necessary to reject or attenuate strong out-of-band signals and the intermodulation products they cause. If such filters are used they must be calibrated with broadband signals.

B.11 Amplitude accuracy

The amplitude accuracy of a spectrum analyzer or a scanning measuring set may be verified by using a signal generator, power meter and precision attenuator. The characteristics of these instruments, cable and mismatch losses have to be analyzed to estimate the errors in the verification test.

Annex C
(informative)

Historical background to the method of measurement of the interference power produced by electrical household and similar appliances in the VHF rang
(see 3.1)

C.1 Historical detail

Although measurement of field strength is, in theory, the most suitable for determining the interference capability of all types of appliances at frequencies higher than 30 MHz, the methods involved together with the precautions to be taken prove troublesome in application. Consequently, engineers have for a long time used the terminal voltage method, while waiting for something more satisfactory. Several methods have been envisaged to replace those involving field measurements in open air by radiation measurements in the laboratory. Among the most interesting are the stop filter method and the ground current method. These are substitution methods, in which a slotted coaxial filter having negligible losses is used to adjust the radiating length of the supply lead of the source of interference in such a way as to obtain maximum radiation. In these methods, the interference capability of an appliance is defined as the power which a standard generator must inject into a simple aerial of known characteristics in order to obtain the same effect on an aerial connected to the measuring apparatus as that produced by the source of interference. Several more convenient methods have been developed from those just mentioned.

The measurement of terminal voltages has been considerably improved by replacing the artificial mains V-network by a Y-network, so as to obtain the true common mode voltage produced by the source of interference. A similar method using a reactive slotted coaxial filter was developed. A method for measuring the power which the source of interference may inject into the supply lead has also been proposed. This method is based on the measurement of the current at the input of an *absorbent* coaxial device.

The advantage of the latter over the terminal voltage method is that it is not necessary to disconnect the supply lead. It indicates values of the interference power corresponding closely with those obtained by the methods in which the radiation of the supply lead is measured in the resonant condition.

Although, through their ease of operation, the terminal voltage and the absorbing coaxial device methods were preferable to the stop filter and the ground current methods, it remained to be shown that the results which they gave conformed with those obtained in practice.

Statistical measurements on the disturbance sources have shown that the interference measured by the stop filter method agrees more closely than that measured by the terminal voltage method, with the effect of the same sources measured at the input of receivers located in the same building. Measurements made by the absorbent device method gave results intermediate between the two previous ones. Other methods have been compared.

C.2 Development of the method

In the stop filter method, a value directly related to the current at the centre of a resonant half-wave aerial is measured. The most important thing is not the radiating system but the power that the source of interference is capable of transmitting to the radiating system. The same principle applies to the ground current method. If it were possible to measure this power without measuring a field, all the disadvantages arising from the influence of surrounding objects on the propagation between the radiating elements and the receiving aerial would be removed. The attempt to replace the coaxial stop filter by a ferrite tube showed that a large part of the energy produced by the source of interference was dissipated in this tube. It was then thought that the measurement of the current at the input of the ferrite tube might replace, at least in part, the measurement of the field by the stop filter method. This gave rise to the devices described in Annex J of CISPR 16-1.

The following question was then studied: how do the different methods of measurement compare in the particular case of a *shielded source* of interference of given available power, with a purely resistive internal impedance when transmitting all its interference energy to the supply lead in the common mode when the size of this source is varied? Experimental investigations showed the remarkable fact that the new device gave results which were practically independent of the dimensions of the source of interference (3,5 dm^3 to 1 700 dm^3) and which were also more consistent than those obtained by other methods.

In fact, one can reduce the absorbing device measuring system to the following circuit: a source of interference of internal impedance Z_S supplying a load Z_C through a low-loss line of characteristic impedance Z_L. If the length of the line is varied from zero, the power absorbed by the load Z_C passes (when Z_C is different from Z_L) through maxima and minima corresponding to resonance and anti-resonance of the system.

Neglecting the radiation and other losses of the line and discussing the case in which the load is located at a distance corresponding to the first maximum, we consider the point in the line at which the source and the load appear as pure resistance R_S and R_C. It can thus be shown that if P_d is the available power of the source, P_C the power absorbed by the load and

$$m=\frac{R_s}{R_c}$$

then

$$\frac{P_c}{P_d}=\frac{4m}{(m+1)^2}$$

This gives for

m =	0,1	0,2	0,5	1	2	5	10	20	30
$M=10\lg\frac{P_c}{P_d}$ =	–4,8	–2,5	–0,5	0	–0,5	–2,5	–4,8	–7,4	–9 dB

It will be seen that the matching of the source to the lead is not very critical and that, if an absorbent clamp is used to constitute a load, for example of the order of 200 Ω, the results obtained will not be very different from those obtained if a load is applied to the output of the source of interference in the form of a line brought to resonance by means of a coaxial stop filter.

Annex D
(informative)

Decision tree for use of detectors for conducted measurements
(see 2.4.2.1)

The following decision tree and notes provide guidance on the pass/fail criteria and the use of detectors for conducted disturbance measurements when the product specification requires measurements with both the quasi-peak and average detectors. For efficiency in performing these measurements, path 1 in Figure D.1 showing the use of the peak detector is recommended.

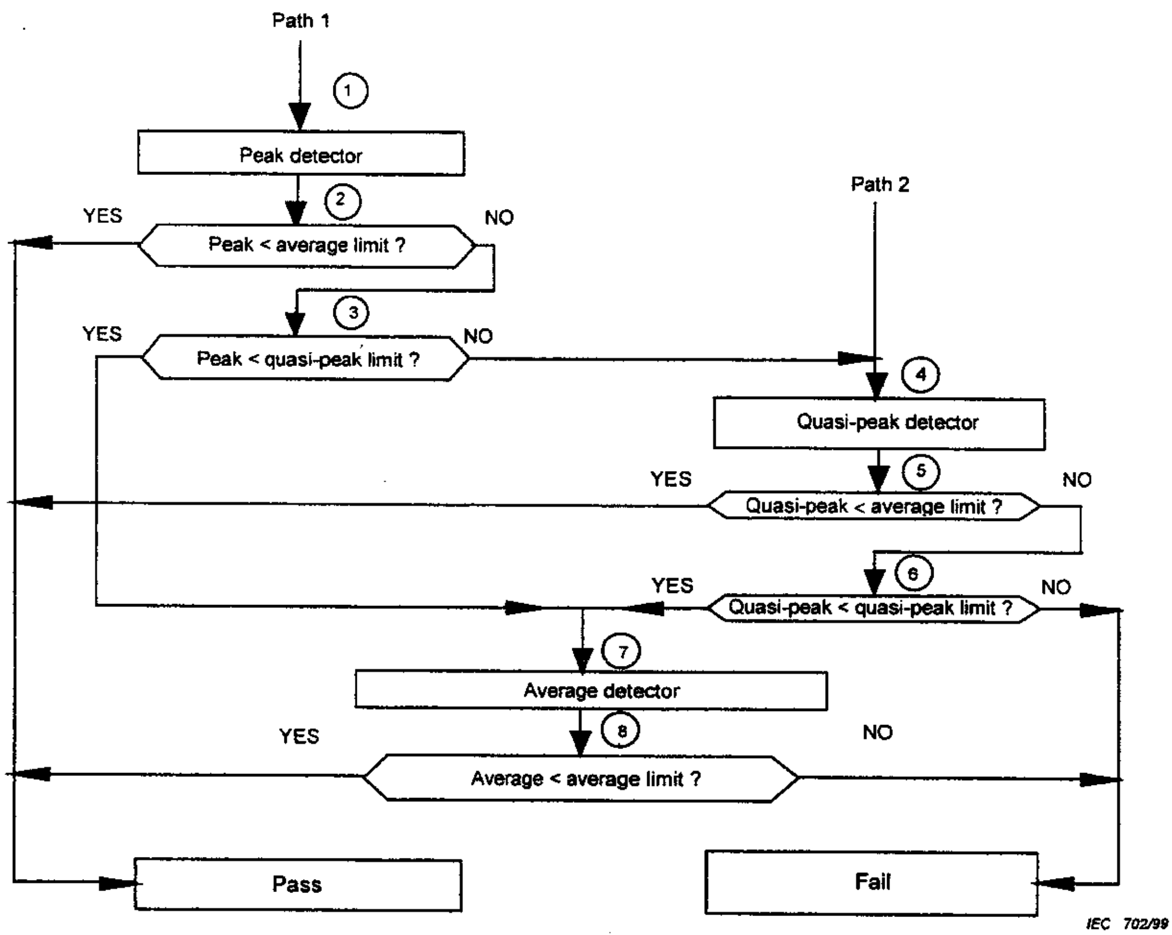


Figure D.1 – Decision tree for optimizing speed of conducted disturbance measurements with peak, quasi-peak and average detectors

NOTE For the EUT to pass, the measured conducted emission must comply with both the quasi-peak and average limits. The tests may be performed using either path 1 or path 2; however, to optimize the speed of conducted disturbance measurements path 1 is recommended. Path 2, starting with a quasi-peak measurement, is slower in situations where compliance with the quasi-peak limit could already be determined from a peak measurement.

1) Start measurement with peak detector for rapid measurement.

2) Compare peak emission level to average limit.
If emissions are above limit: go to step 3.
If emissions are below limit: EUT passes.

3) Compare peak emission level with quasi-peak limit.
If emissions are above limit: go to step 4.
If emissions are below limit: go to step 7.

4) Measurement with quasi-peak detector.

5) Compare quasi-peak emission level to the average limit.
If emissions are above limit: go to step 6.
If emissions are below limit: EUT passes.

6) Compare quasi-peak emission level to the quasi-peak limit.
If emissions are above limit: EUT fails.
If emissions are below limit: go to step 7.

7) Measurement with average detector.

8) Compare average emission level to the average limit.
If emissions are above limit: EUT fails.
If emissions are below limit: EUT passes.

When frequency scanning is used during the peak measurement, the scan rate of the spectrum analyzer or scanning receiver should be adjusted not to exceed the fastest scan rate listed in Annex B.

Annex E
(informative)

Measurement of disturbances in the presence of ambient emissions

E.1 General

High ambient emissions have to be taken into account during *in situ* tests (conducted and radiated) and type tests on an Open Area Test Site (OATS). It is the purpose of this annex to describe measurement procedures for a number of different situations.

In some circumstances, the procedures will not provide a solution to the problems caused by ambient signals. In particular, the procedures cannot be expected to overcome the problems of 5.6.4 of CISPR 16-1:1999. But without this requirement the document can be used.

E.2 Definitions

E.2.1
EUT disturbance
EUT emission spectrum to be measured

E.2.2
ambient emission
emission spectrum superimposed on the EUT disturbance spectrum which influences the accuracy of the EUT disturbance measurement

NOTE This method does not consider the procedures of 10.6 of CISPR 22:1997.

E.3 Problem description

During *in situ* tests and type tests on an OATS the ambient emissions frequently do not correspond to the recommendations of 5.6.4 (Ambient radio frequency environment of a test site) of CISPR 16-1:1999.

The radio disturbance of the EUT is often located within the frequency bands of ambient emissions and can not be measured with a radio disturbance measuring receiver as specified in CISPR 16-1 due to insufficient frequency spacing between the EUT disturbance and the ambient emission or due to superposition.

The standard CISPR measuring receiver is suitable to provide uniform test results for all kinds of radiofrequency emissions, where the EUT disturbance alone is to be measured. It is, however, not optimized to discriminate between EUT disturbance and ambient emissions or to measure the EUT disturbance in the described situation.

Since in actual interference situations there are no alternatives to the *in situ* test, a solution is described below for cases when a differentiation between EUT disturbance and ambient emission is possible.

E.4 Proposed solution

E.4.1 Overview

EUT disturbance and ambient emissions can be categorized as follows:

Table E.1 – Combinations of EUT disturbance and ambient emissions

EUT disturbance	Ambient emission
Narrowband	Narrowband
	Broadband
Broadband	Narrowband
	Broadband

Narrowband ambient emissions may be, for example, AM- or FM-modulated; broadband ambient emissions may be, for example, TV or digitally modulated signals. Here the terms "narrowband" and "broadband" are always relative to the bandwidth of the measuring receiver, as specified in CISPR 16-1. Narrowband signals are defined as signals that have a bandwidth less than the measuring receiver bandwidth. In this case, all the signal's spectral components are contained in the receiver bandwidth. A CW signal will always be narrowband; a narrow FM signal can be both narrow or broadband, depending on the actual receiver bandwidth. On the contrary, an impulsive signal will usually be broadband because a few of its spectral components will be within and many of its spectral components outside the receiver bandwidth.

The measurement of the EUT disturbance is a manifold problem: first, to identify EUT disturbance and ambient emission and, second, to distinguish between narrowband and broadband emission. Modern measuring receivers and spectrum analysers provide various resolution bandwidths and detector types. These can be used to analyse the combined spectrum, to distinguish between EUT disturbance and ambient emission spectra, to distinguish between narrowband and broadband emissions and to measure (or in difficult situations to estimate) the EUT disturbance.

In case of type testing on an OATS, identification and pre-measurement of the EUT disturbance may also be carried out by pretesting the EUT in a non-compliant (for example, partially) absorber-lined shielded room, and final testing on an OATS, whereby levels of emissions hidden by ambients may be determined by comparison with emissions in the vicinity.

Superposition of the emissions has to be taken into account when EUT disturbance and ambient emissions cannot be separated. The separation needs a EUT disturbance-and-ambient-emission to ambient-emission ratio of about 20 dB.

In cases where IF-bandwidths and detectors are different from the specified bandwidth and the quasi-peak (QP) detector, the QP value in the specified bandwidth is the reference for the measurement-error determination.

Figure E.1 shows a flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection.

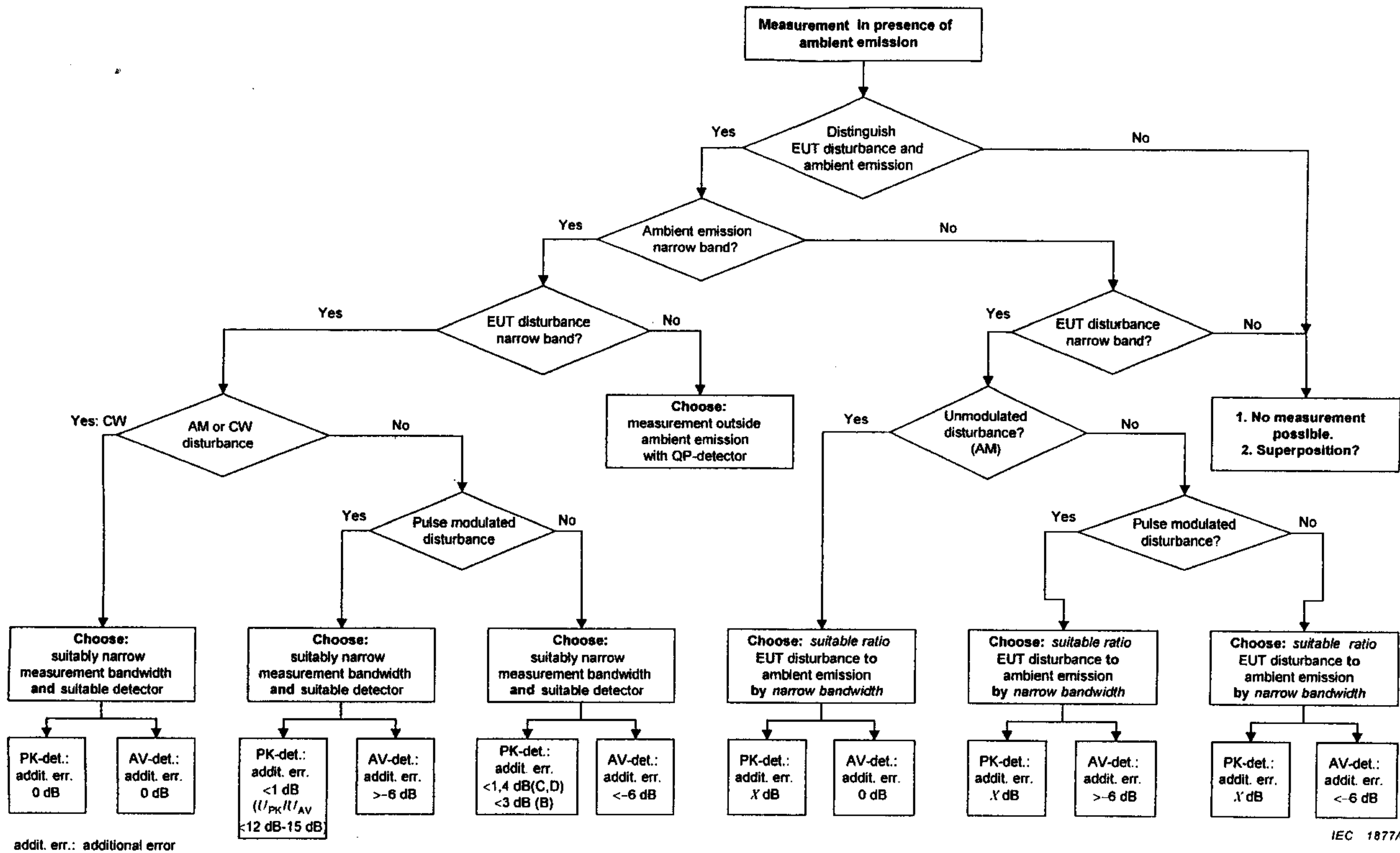


Figure E.1 – Flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection

E.4.2 Pre-testing the EUT in a shielded quiet chamber

One can use the emission frequency and amplitude data, acquired in shielded quiet-chamber preliminary testing under certain restrictive conditions (since this shielded quiet chamber is an absorber-lined shielded room – semi-anechoic or anechoic – which does not meet present NSA values in Annex G of CISPR 16-1 (Annex A in CISPR 22)). This will give the emission spectrum which has significant amplitudes. In cases of narrowband emission the product emission spectrum contains harmonics and subharmonics of any clock frequency used in the product.

These pre-test results may be used to determine product emission amplitudes in certain restrictive situations. In particular, when the final compliance test is performed at an OATS and one (or more) of the frequencies are masked (hidden) by an RF ambient, chances are that an adjacent frequency to these masked frequencies will not coincide precisely with an RF ambient. Hence, the unmasked emission can be recorded in the usual manner using the required receiver or spectrum analyser bandwidth. Then the amplitude of the EUT emission which is masked by the high RF ambient can be judged using the preliminary quiet-chamber measurements in the following way.

Assume that during the quiet-chamber preliminary measurements two adjacent frequency emissions are X dB different in amplitude (see Figure E.2). Then one of these frequencies that are not masked by the RF ambient is measured at the OATS. The difference in amplitude ("X dB") of the masked frequency from the measurable adjacent frequency can be added to (or subtracted from, depending on the sign of the difference) the amplitude found in the quiet chamber to determine the amplitude of the adjacent frequencies. This is shown in Figure E.2, where (assuming that the frequency f_1 is the masked frequency and f_0 is not masked), the amplitude for f_1 is shown as X dB greater than the amplitude at f_0. Then to find the amplitude of f_1 at the OATS, X dB is added to the value of the measurable amplitude of f_0. Similarly, if the amplitude of f_6 were Y dB less than that for f_7 found during the quiet- chamber testing, the amplitude of f_6 (if masked by an ambient) would be Y dB less than that of f_7 which is assumed to be measurable at the OATS.

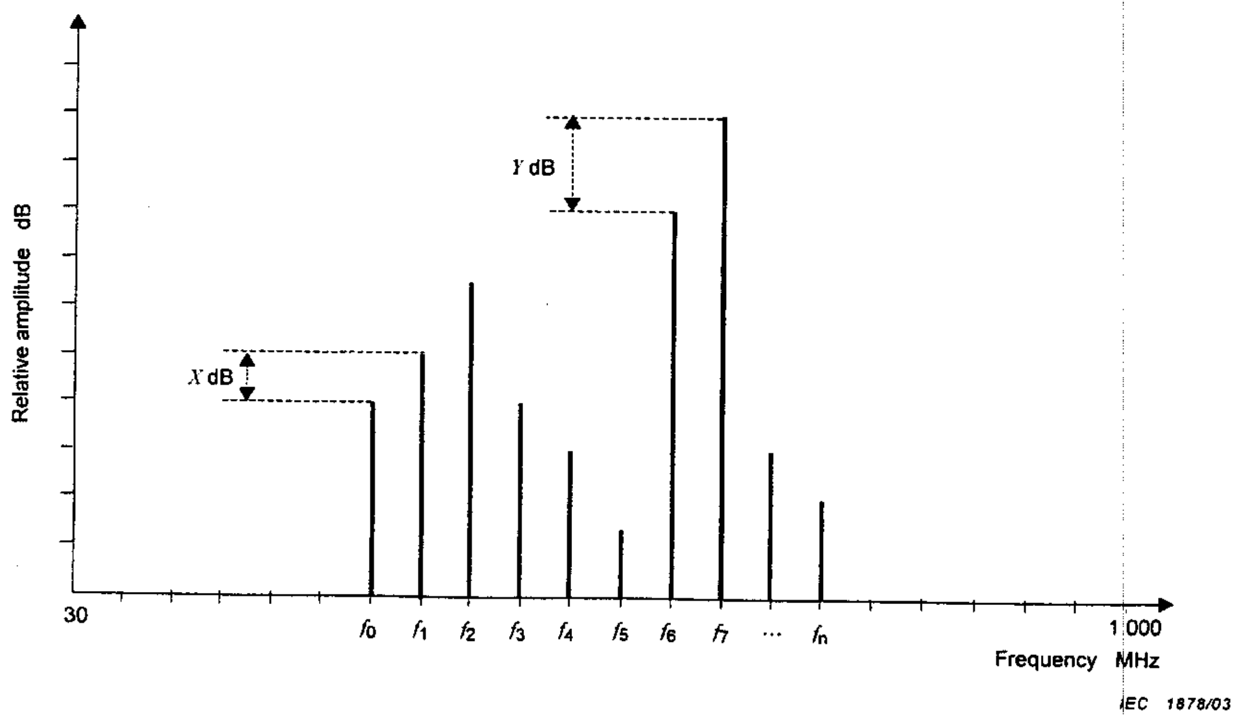


Figure E.2 – Relative difference in adjacent emission amplitudes during preliminary testing

NOTE The above procedure amplifies what is contained in point c) of 2.6.2.5.1 (Test environment).

Several precautions should be taken in using this restrictive procedure.

The adjacent frequency found in preliminary testing should not be more than one or two adjacent frequencies (usually a subharmonic or harmonic of the basic clock frequency) away, so that the effect of the quiet-chamber irregularities will not unnecessarily enhance or depress frequencies adjacent to the frequency to be estimated on the OATS. In this case, the value of "*X*" (or *Y* in Figure E.2) may not be suitable.

a) The amplitudes of adjacent frequencies need to be measured very carefully by height scan of the receive antenna in the quiet chamber (as would be the case for the final compliance measurement). If full height scan cannot be made, alternate correlations between the quiet-chamber measurements and the corresponding OATS measurements may have to be made before applying this OATS amplitude estimation technique (for emissions masked by the RF ambient).
b) For those quiet chambers which are fully anechoically treated on all six sides of the chamber, alternate height-scan techniques might be available, such as measurements at two or three fixed heights (since the ground plane reflections are suppressed and that contribution to the received signal diminished) and using the maximum of these readings. Such techniques may need the same correlation measurements as stated in item b) above.

E.4.3 Method of measurement of EUT disturbances in the presence of narrowband ambient emissions

Depending on the type of EUT disturbance its measurement is based on

- the analysis of the combined spectrum with a bandwidth narrower than that of the CISPR measuring receiver;
- the determination of a suitable measurement bandwidth for the selection of narrowband disturbance close to ambient emissions;
- the use of the peak detector (if the disturbance is AM or pulse modulated) or the average detector;
- the increase of the EUT disturbance to ambient emission ratio in case of a narrowband disturbance within a relatively broadband ambient emission when a narrower measurement bandwidth is used; and
- accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

E.4.3.1 Unmodulated EUT disturbance

The unmodulated EUT disturbance (see Figure E.3) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Either the peak or the average detector may be used. There is no additional measurement error compared with the quasi-peak detector. If the difference in level between peak and average values is very small (for example, lower than 1 dB), the measured average value is equivalent to the quasi-peak value.

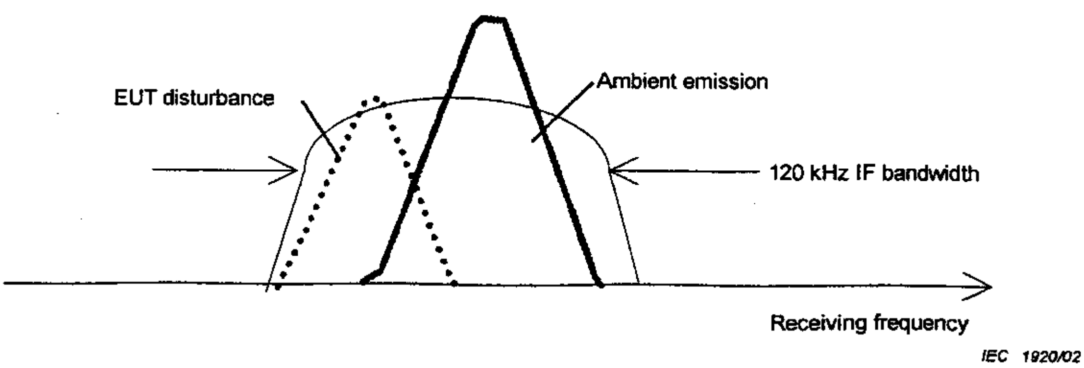


Figure E.3 – Disturbance by an unmodulated signal (dotted line)

E.4.3.2 Amplitude-modulated EUT disturbance

The amplitude-modulated EUT disturbance (see Figure E.4) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Care should be taken to ensure that the narrow measurement bandwidth chosen does not suppress the modulation spectra of the EUT disturbance. Suppression of the modulation spectra is recognised by a decrease in the peak amplitude of the EUT disturbance as a result of the increase of selectivity.

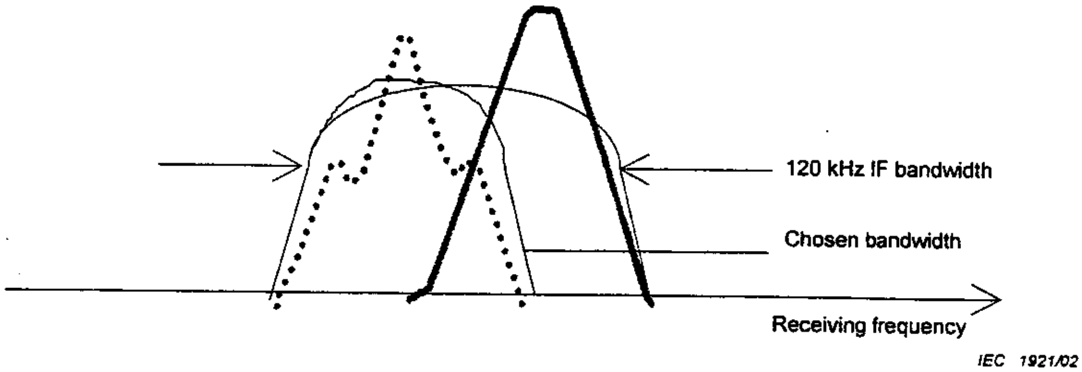


Figure E.4 – Disturbance by an amplitude-modulated signal (dotted line)

Only the peak detector with a measurement time greater than the reciprocal of the modulation frequency can be used. An additional measurement error has to be taken into account at modulation frequencies below 10 Hz (0,4 dB at 10 Hz; 1,4 dB at 2 Hz for bands C and D and 0,9 dB at 10 Hz; 3 dB at 2 Hz for band B), where the peak value is above the quasi-peak value.

The QP-value in response of the modulation frequency is shown in Figure E.5.

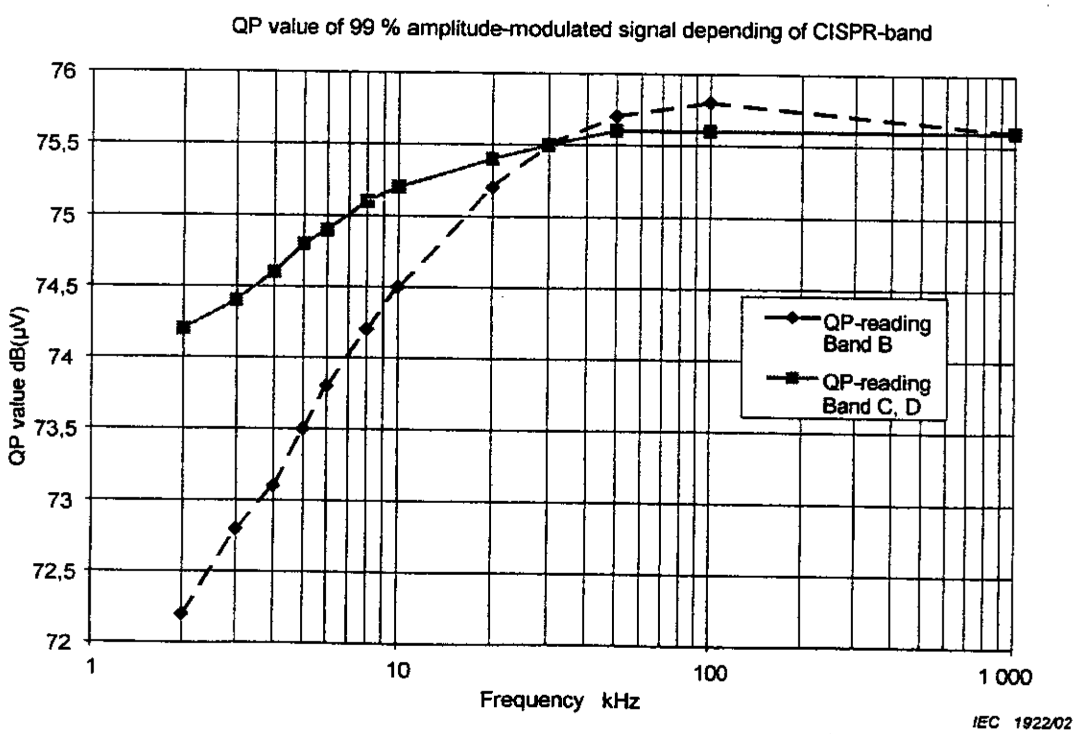


Figure E.5 – Indication of an amplitude-modulated signal as a function of modulation frequency with the QP detector in CISPR bands B, C and D

E.4.3.3 Pulse-modulated EUT disturbance

The narrowband pulse-modulated disturbance from the EUT is classified as a special case of amplitude modulation and can also be separated from the ambient signal carrier by a suitably narrow measurement bandwidth. The selectivity must not lead to a suppression of the modulation spectra. Only the peak detector can be used.

In cases of low repetition frequency, an additional error is possible, but as long as the difference between peak- and average detector reading is in the order of 12 dB to 14 dB, additional measurement errors compared with the quasi-peak value need not be taken into account.

For a pulse width t = 50 µs, Figure E.6 shows that as long as the difference between peak and average levels is less than or equal to 14 dB, the deviation between peak and QP levels is negligible. So, the comparison between peak and average levels may be used to verify the usability of the peak detector.

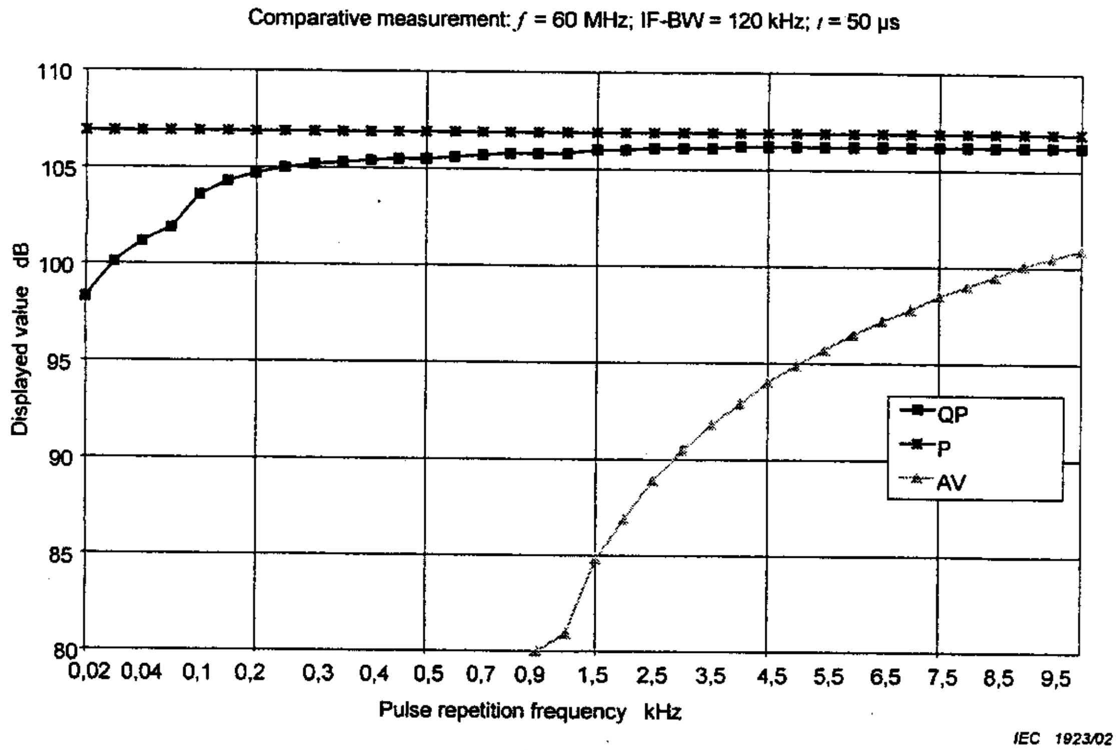


Figure E.6 – Indication of a pulse-modulated signal (pulse width 50 µs) as a function of pulse repetition frequency with peak, QP and average detectors

E.4.3.4 Broadband EUT disturbance

For the measurement of broadband disturbance (see Figure E.7) the quasi-peak detector has to be used.

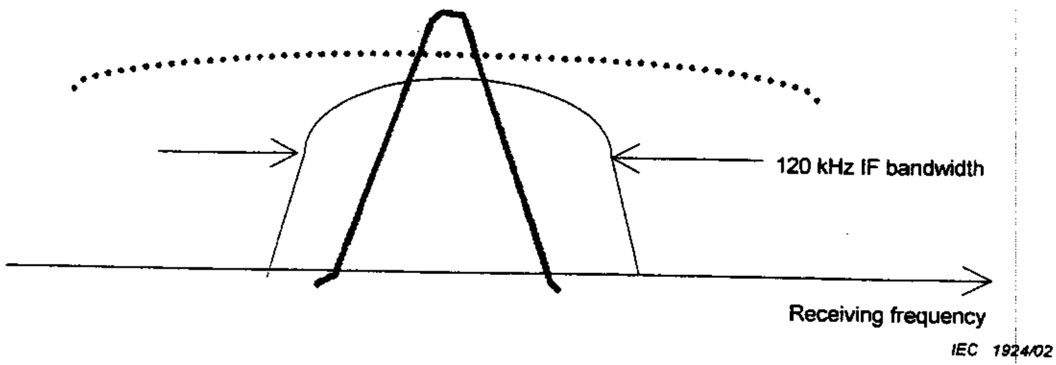


Figure E.7 – Disturbance by a broadband signal (dotted line)

As a rule it is not possible to carry out a measurement within the ambient signal band. Due to its bandwidth the disturbance can generally be measured outside the ambient signal spectrum using the quasi-peak detector.

E.4.4 Method of measurement of EUT disturbance in the presence of broadband ambient emissions

In this case the measurement method is based on

- the analysis of the combined spectrum with a bandwidth equal to the CISPR measuring receiver;
- measurement with a narrow bandwidth (in case of narrowband EUT disturbance; the use of a narrow bandwidth will increase the EUT disturbance to ambient emission ratio);
- the use of the average detector for narrowband EUT disturbance; and
- accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

E.4.4.1 Unmodulated EUT disturbance

The amplitude of the EUT disturbance (see Figure E.8) should be measured with the average detector (specified in CISPR 16-1). The measurement error depends on the average value of the broadband signal spectrum within the selected bandwidth. This measurement error can be minimized by choosing a measurement bandwidth which maximizes the EUT disturbance to ambient emission ratio (selectivity method).

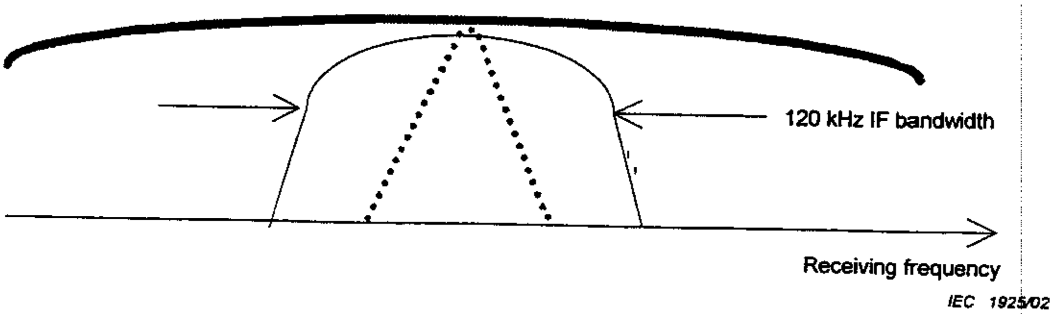


Figure E.8 – Unmodulated EUT disturbance (dotted line)

E.4.4.2 Amplitude-modulated EUT disturbance

The amplitude of the EUT disturbance (see Figure E.9) is measured with the average detector, although an additional measurement error of up to 6 dB (at 100 % modulation) compared with a quasi-peak detector has to be taken into account. The measurement bandwidths chosen should maximize the EUT disturbance to ambient emission ratio (selectivity method).

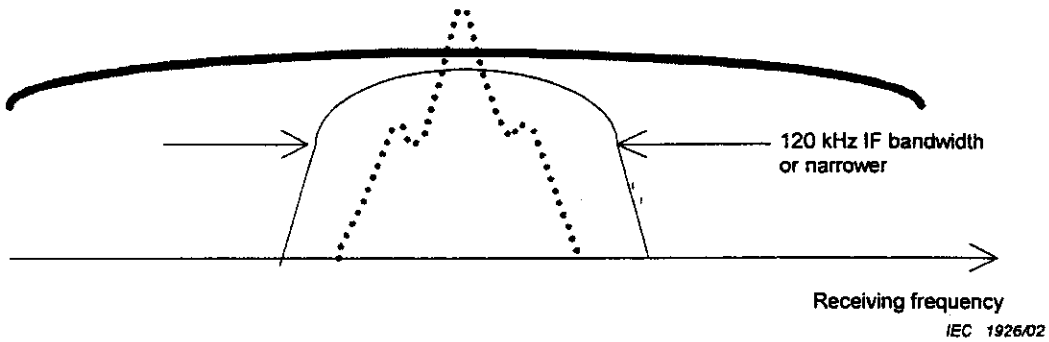


Figure E.9 – Amplitude-modulated EUT disturbance (dotted line)

E.4.4.3 Pulse-modulated EUT disturbance

It is not easy to detect and recognise a pulse-modulated EUT disturbance in a broadband ambient signal spectrum with a high level of reliability since the 100 % amplitude modulation of the disturbance may disperse the EUT disturbance in the spectrum.

The amplitude of the EUT disturbance can be measured with the average detector in case of high duty cycles. Due to the 100 % amplitude modulation depth with smaller duty cycles, the use of the average detector will cause an increasing measurement error compared with the quasi-peak detector. In the case of a duty cycle of 1:1 and use of the linear average detector, the measurement error is 6 dB. The measurement bandwidth should be such that the relationship between the measured average value of the EUT disturbance and the average value of the broadband ambient signal is maximized.

In case of low duty cycles, the average value will substantially deviate from the QP value. In this case the peak detector should be used together with a measurement bandwidth as narrow as possible but still wide enough to capture the complete disturbance bandwidth. Superposition with the ambient emission may have to be taken into account.

E.4.4.4 Broadband EUT disturbance

As a rule, broadband disturbance cannot be detected or measured in a broadband ambient signal spectrum; it may be possible to measure such a disturbance outside the ambient signal spectrum or by taking superposition into account.

The combinations of EUT disturbance with the ambient emission and the error involved in the measurement are displayed in Table E.2.

NOTE A scanning receiver or spectrum analyser will show the spectra of two different broadband signals unless the signal frequencies or pulse rates are harmonically related with each other or the sweep rate of the measuring instrument is harmonically related with the measured pulse rates.

E.5 Determination of the EUT disturbance in case of superposition

If, as a result of the selection of the EUT disturbance and the ambient emission, the measured level to ambient emission ratio is lower than 20 dB, the superposition of ambient emission and EUT disturbance needs to be taken into account. For impulsive broadband voltage the following calculation can be made.

The received signal U_r is the sum of the EUT disturbance U_i and the ambient emission U_a. U_a can be measured only when the EUT is switched off. The superposition is linear for the peak detector (Figure E.10). The following equation applies using the peak detector:

$$U_r = U_i + U_a. \qquad \text{(E.1)}$$

The EUT disturbance can thus be calculated from

$$U_i = U_r - U_a \qquad \text{(E.2)}$$

The amplitude ratio d of the received signal to the ambient emission can be measured easily.

$$D = \frac{U_r}{U_a} \qquad d = 20 \log D \qquad \text{(E.3)}$$

The ambient emission U_a can be substituted in equation (E.2):

$$U_i = U_r - \frac{U_r}{D} = U_r\,(1 - \frac{1}{D}) \qquad \text{(E.4)}$$

or

$$U_i \,/\, \text{dB} = U_r \,/\, \text{dB} + 20 \log\,(1 - \frac{1}{D}) \qquad \text{(E.5)}$$

"i" in equation (E.6)

$$i = -20 \log\,(1 - \frac{1}{D}) \qquad \text{(E.6)}$$

serves to determine the amplitude of the EUT disturbance. "i" is illustrated in E.11. Using "i" from Figure E.11, the amplitude of the EUT disturbance can be calculated as follows:

$$U_i \,/\, \text{dB} = U_r \,/\, \text{dB} - i \,/\, \text{dB} \qquad \text{(E.7)}$$

If the received signal is measured with the average detector, Figure E.12 can be taken into account. It is shown in Figure E.12 that in the case of unmodulated signals the following equation

$$U_r = \sqrt{U_i^{\,2} + U_a^{\,2}} \qquad \text{(E.8)}$$

can be used with an additional measurement error of up to about 1,5 dB. In case of modulation, the error decreases (see Figure E.12) but the errors in Table E.2 have to be taken into account.

By means of the average detector, the inband disturbance can be estimated by applying equation (E.7) if the curve of the average detector (Figure E.11) is used. In this case the factor i is expressed by the following equation.

$$i = -10 \log\,(1 - \frac{1}{D^2}) \qquad \text{(E.9)}$$

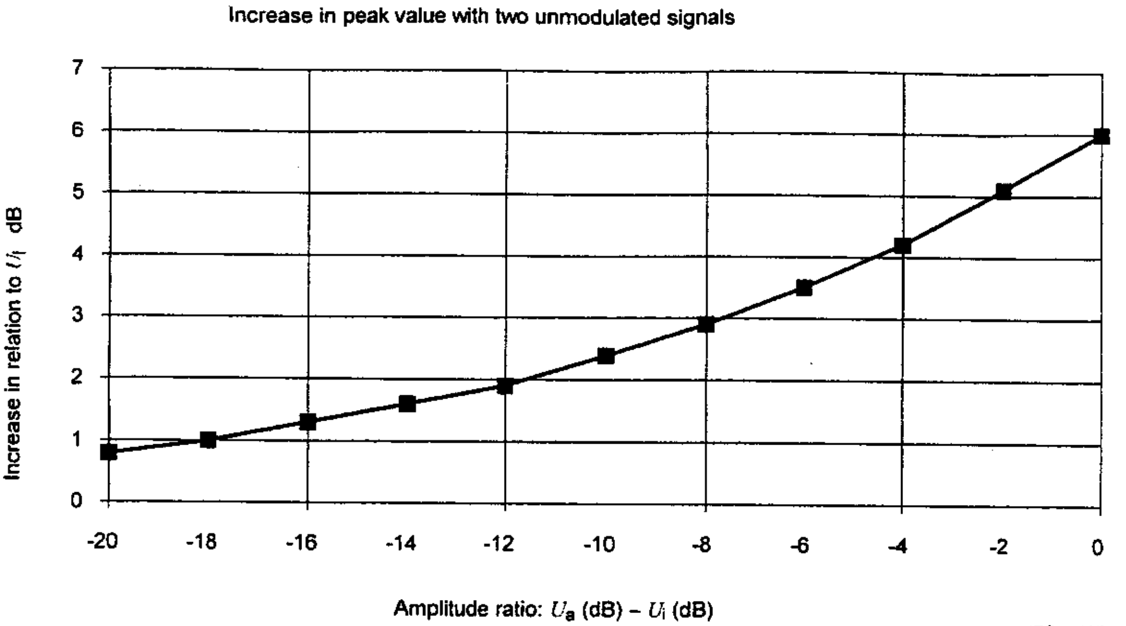
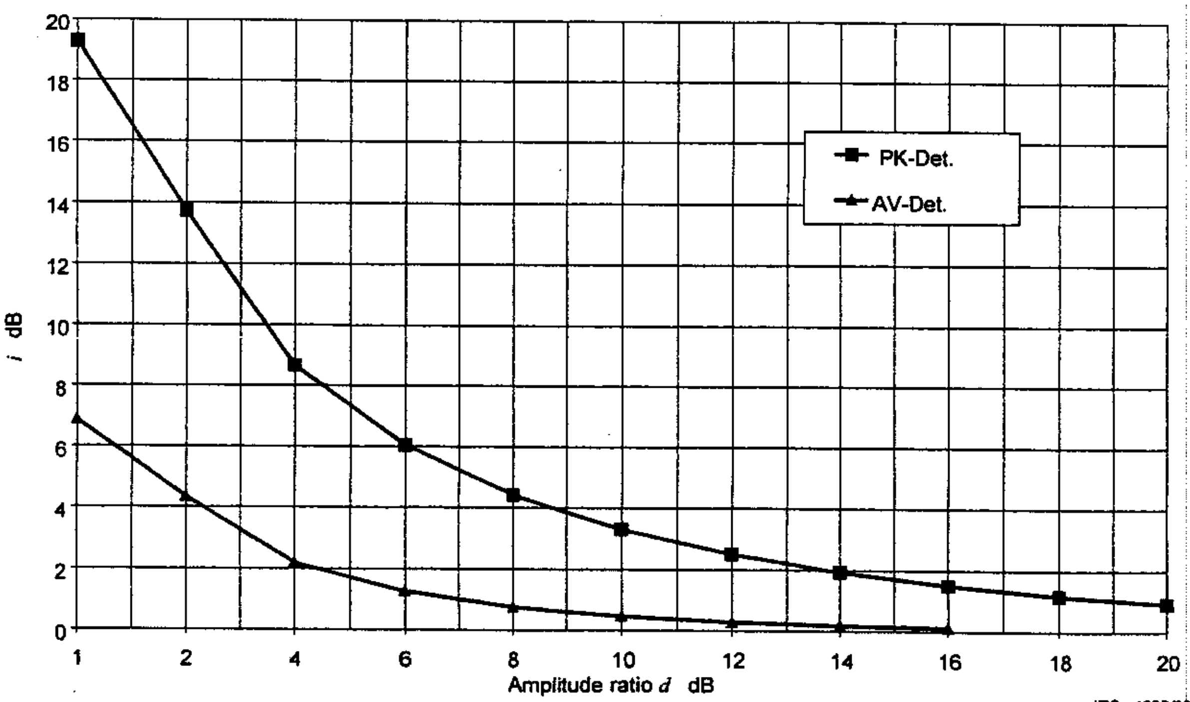


Figure E.10 – Increase of peak value with superposition of two unmodulated signals
(U_a - level of ambient emission; U_i - level of EUT disturbance)



$d = U_r - U_a$ $\qquad U_i = U_r - i$ $\qquad i = -20\log(1 - \frac{1}{D})$

where

U_a is the ambient signal in dB

U_r is the resulting indication of received signal (by superposition) in dB

U_i is the disturbance signal in dB

Figure E.11 – Determination of the amplitude of the disturbance signal by means of the amplitude ratio d and the factor i

Figure E.11 can be used as follows:

1) measure the ambient field strength U_a in dB(µV/m) (EUT off);
2) measure the resultant field strength U_r in dB(µV/m) (EUT on);
3) determine $d = U_r - U_a$;
4) find the value of i from Figure E.11;
5) determine U_i in dB(µV/m) using $U_i = U_r - i$.

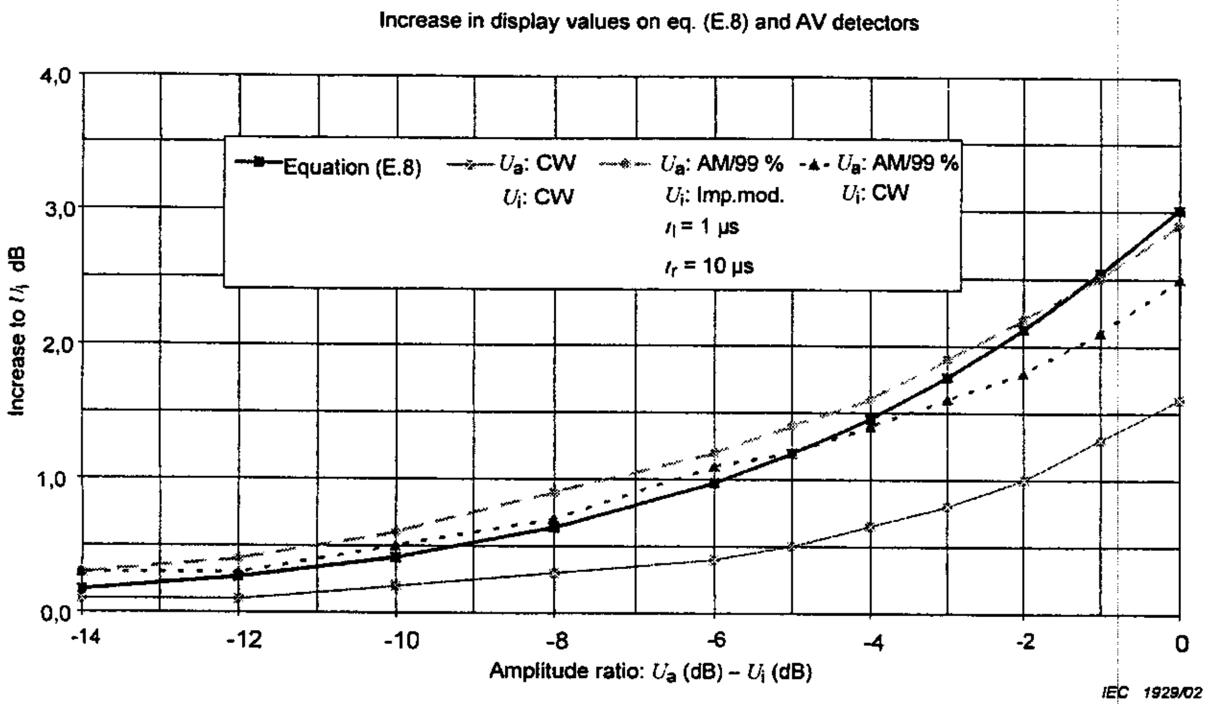


Figure E.12 – Increase of average indication measured with a real receiver and calculated from equation (E.8)

Table E.2 – Measurement error depending on the detector type and on the combination of ambient and disturbing signal spectra

Ambient emission	EUT disturbance			
	Unmodulated	Amplitude-modulated	Pulse-modulated	Broadband disturbance
Narrowband				
Steps taken to increase signal-to-noise ratio	Increased selectivity	Increased selectivity	Increased selectivity	Measurement outside ambient emission
Error of peak value $\left(\frac{PK}{QP}\right)$	0 dB	Less than or equal to +1,4 dB for bands C,D +3 dB for band B	Less than or equal to +1 dB $\left(\frac{U_{PK}}{U_{AV}} \leq 12...15\ \text{dB}\right)$	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–
Broadband				
Steps taken to increase signal-to-noise ratio	Selectivity	Selectivity	Selectivity	No measurement possible (superposition only)
Error of peak value $\left(\frac{PK}{QP}\right)$	$+X$ dB [a]	Less than or equal to +X dB [a]	Greater than or equal to $+X$ dB [a]	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–

[a] Measurement procedure not recommended, for compliance measurements not allowed.

NOTE 1 X is the error depending on the pulse character of the ambient emission.

NOTE 2 PK is the peak value; QP is the quasi-peak value; AV is the average value.

Annex F
(informative)

Example of the uncertainty budget

A measurement uncertainty budget for emission in a 3 m distance FAR will show the influence factors and their practical weighting (see Table F.1). It will be part of CISPR 16-4.

Table F.1 – Uncertainty budget for emission measurements in a 3 m FAR

Component	Probability distribution	Uncertainty dB	
		Bicon	LPDA
Antenna factor calibration	normal (k = 2)	± 2,0	± 2,0
Cable loss calibration	normal (k = 2)	± 0,5	± 0,5
Receiver specification according to CISPR 16-1	rectangular	± 1,5	± 1,5
Antenna directivity [a]	rectangular	+1,0	± 1,0
Antenna factor variation with height	rectangular	0	0
Antenna phase centre variation [b]	rectangular	0	± 0,5
Antenna factor frequency interpolation	rectangular	± 0,3	± 0,3
Measurement distance uncertainty ± 3 cm [c]	rectangular	± 0,1	± 0,1
Site imperfections [d]	rectangular	± 3,0	± 2,5
Mismatch	U-shaped	± 1,1	± 0,5
Combined standard uncertainty $u_c(y)$	normal	± 2,414	± 2,114
Expanded uncertainty U	normal (k = 2)	± 4,828	± 4,228

[a] Antenna directivity is relative to a tuned dipole that is the reference antenna stipulated by CISPR 16-1. For a biconical antenna the uncertainty is for vertical polarisation, it being zero for horizontal polarisation. The uncertainty is positive because it represents only loss of signal.

[b] Increasingly hybrid biconical/log. period antennas are used. Correction of field strength against phase centre position is more accurate in the absence of a ground reflection. This uncertainty term is of course less for shorter antennas.

[c] The distance uncertainty is negligible, because there is only a limited height scanning and no diagonal distance may appear.

[d] If the uncertainty due to the site alone is ± 3 dB when using a biconical as the receive antenna, it is likely to be less when using a directional log antenna, so it has been set to ± 2,5 dB for the LPDA.

Calculation of the combined uncertainty for the biconical antenna in a FAR:

$$u_c(y)=\sqrt{(\frac{2,0}{2})^2+(\frac{0,5}{2})^2+\frac{1,5^2+1^2+0^2+0^2+0,3^2+0,1^2+3,0^2}{3}+\frac{1,1^2}{2}}$$

In this example a coverage factor of k = 2 will ensure that the level of confidence will be approximately 95 %, therefore:

$$U = 2u_c(y) = 2 \times (+2,62) = \pm 4,828 \text{ dB}$$