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BASIC EMC PUBLICATION
PUBLICATION FONDAMENTALE EN CEM

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

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

Partie 2-1: Méthodes de mesure des perturbations et de l'immunité – Mesures des perturbations conduites



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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

**Part 2-1: Methods of measurement of disturbances and immunity –
Conducted disturbance measurements**

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This third edition cancels and replaces the second edition published in 2008, Amendment 1:2010 and Amendment 2:2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: Methods of measurement using a new type of ancillary equipment – the CDNE – are added.

The text of this standard is based on the following documents:

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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.

A list of all parts of CISPR 16 series under the general title *Specification for radio disturbance and immunity measuring apparatus and methods*, can be found on the IEC website.

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SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

1 Scope

This part of CISPR 16 is designated a basic standard, which specifies the methods of measurement of disturbance phenomena in general in the frequency range 9 kHz to 18 GHz and especially of conducted disturbance phenomena in the frequency range 9 kHz to 30 MHz. With a CDNE, the frequency range is 9 kHz to 300 Hz.

NOTE In accordance with IEC Guide 107, CISPR 16 is a basic EMC standard for use by product committees of the IEC. As stated in Guide 107, product committees are responsible for determining the applicability of the EMC standard. CISPR and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular EMC tests for specific products.

2 Normative references

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

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

CISPR 16-1-1:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements*

CISPR 16-4-2, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161, as well as the following apply.

3.1.1

ancillary equipment

transducers (e.g. current and voltage probes and artificial networks) connected to a measuring receiver or (test) signal generator and used in the disturbance signal transfer between the EUT and the measuring or test equipment

3.1.2

artificial network

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

Note 1 to entry: This note applies to the French language only.

3.1.3

artificial mains network

AMN

network that provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver, and decouples the test circuit from the supply mains

Note 1 to entry: There are two basic types of this network, the V-network (V-AMN) which couple the unsymmetric voltages, and the delta-network (Δ -AMN), which couple the symmetric and the unsymmetric voltages separately.

Note 2 to entry: The terms line impedance stabilization network (LISN) and V-AMN are used interchangeably.

Note 3 to entry: This note applies to the French language only.

3.1.4

associated equipment

AE

apparatus, which is not part of the system under test, but needed to help exercise the EUT

Note 1 to entry: This note applies to the French language only.

3.1.5

asymmetric artificial network

AAN

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

Note 1 to entry: An AAN is an AN (artificial network) that provides a simulation of the asymmetric load realized by the telecommunication network.

Note 2 to entry: The term "Y-network" is a synonym for AAN.

Note 3 to entry: The AAN can also be used for immunity testing, where the receiver measurement port becomes the disturbance injection port.

Note 4 to entry: This note applies to the French language only.

3.1.6

asymmetric voltage

radio-frequency disturbance voltage appearing between the electrical mid-point of the mains terminals and ground, sometimes called the common mode voltage

Note 1 to entry: If V_a is the vector voltage between one of the mains terminals and ground, and V_b is the vector voltage between the other mains terminal and ground, the asymmetric voltage is half the vector sum of V_a and V_b , i.e. $(V_a + V_b)/2$.

3.1.7

symmetric voltage

radio-frequency disturbance voltage appearing between the two wires in a two-wire circuit, such as a single-phase mains supply, sometimes called the differential mode voltage

Note 1 to entry: The symmetric voltage is the vector difference $(V_a - V_b)$.

3.1.8

unsymmetric mode voltage

amplitude of the vector voltage, V_a or V_b (defined in 3.6 and 3.7)

Note 1 to entry: The unsymmetric voltage is the voltage measured by the use of an artificial mains V-network.

Note 2 to entry: See notes in 3.6 and 3.7 for details on V_a and V_b .

3.1.9

auxiliary equipment

AuxEq

peripheral equipment which is part of the system under test

Note 1 to entry: This note applies to the French language only.

3.1.10

CDNE-*X*

coupling decoupling network for emission measurement in the frequency range 30 MHz to 300 MHz; where the "*X*" suffix can be "M2" for unscreened two-wire mains, DC or control ports, "M3" for unscreened three-wire mains, DC or control ports, and "S*x*" for screened cable with *x* internal wires

Note 1 to entry: See Annex J in CISPR 16-1-2: 2014 for example CDNE-*X* set-up diagrams.

3.1.11

coaxial cable

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

3.1.12

common mode current

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

3.1.13

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

3.1.14**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

3.1.15**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 to entry: For impulsive disturbance, see IEC 60050-161:1990, 161-02-08.

3.1.16**(electromagnetic) emission**

phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:1990, 161-01-08]

3.1.17**emission limit (from a disturbance source)**

specified maximum emission level of a source of electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-03-12]

3.1.18**equipment under test****EUT**

equipment (devices, appliances and systems) subjected to EMC (emission) compliance tests

Note 1 to entry: This note applies to the French language only.

3.1.19 Measurement, scan and sweep times**3.1.19.1****measurement**

process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

[SOURCE: JCGM 200:2012, 2.1 [12]¹]

3.1.19.2**measurement time** **T_m**

effective, coherent time for a measurement result at a single frequency (in some areas 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 Numbers in square brackets refer to the Bibliography.

3.1.19.3

scan

continuous or stepped frequency variation over a given frequency span

3.1.19.4

span

Δf

difference between stop and start frequencies of a sweep or scan

3.1.19.5

sweep

continuous frequency variation over a given frequency span

3.1.19.6

sweep time

scan time

T_s

time between start and stop frequencies of a sweep or scan

3.1.19.7

sweep rate

scan rate

frequency span divided by the sweep time or scan time

3.1.19.8

observation time

T_o

sum of measurement times T_m on a certain frequency in case of multiple sweeps

Note 1 to entry: If n is the number of sweeps or scans, then $T_o = n \times T_m$.

3.1.19.9

total observation time

T_{tot}

effective time for an overview of the spectrum (either single or multiple sweeps)

Note 1 to entry: If c is the number of channels within a scan or sweep, then $T_{tot} = c \times n \times T_m$.

3.1.20

measuring receiver

instrument such as a tunable voltmeter, an EMI receiver, a spectrum analyzer or an FFT-based measuring instrument, with or without preselection, that meets the relevant clauses of CISPR 16-1-1

Note 1 to entry: See Annex I of CISPR 16-1-1:2010 for further information.

3.1.21

number of sweeps per time unit

n_s

$1/(\text{sweep time} + \text{retrace time})$

Note 1 to entry: For example, sweeps per second.

3.1.22**product standard**

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

3.1.23**protective earthing**

earthing a point or points in a system or in an installation or in equipment, for purposes of electrical safety

[SOURCE: IEC 60050-195:1998, 195-01-11]

3.1.24**reference ground**

reference potential connecting point

Note 1 to entry: There can only be one reference ground in a conducted disturbance measurement system.

3.1.25**reference ground plane****RGP**

flat conductive surface that is used as a common reference and that allows a defined parasitic capacitance to the surroundings of an EUT

Note 1 to entry: A reference ground plane is needed for conducted disturbance measurements, and serves as reference ground for the measurement of unsymmetric and asymmetric disturbance voltage.

Note 2 to entry: This note applies to the French language only.

3.1.26**test**

technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure

Note 1 to entry: A test is carried out to measure or classify a characteristic or a property of an item by applying to the item a set of environmental and operating conditions and/or requirements.

[SOURCE: IEC 60050-151:2001, 151-16-13]

3.1.27**test configuration**

combination that gives the specified measurement arrangement of the EUT in which a disturbance level is measured

3.1.28**total common mode impedance****TCM impedance**

impedance between the cable attached to the EUT port under test and the RGP

Note 1 to entry: The complete cable is seen as one wire of the circuit and the ground plane as the other wire of the circuit. The TCM wave is the transmission mode of electrical energy, which can lead to radiation of electrical energy if the cable is exposed in the real application. Vice versa, this is also the dominant mode, which results from exposure of the cable to external electromagnetic fields.

Note 2 to entry: This note applies to the French language only.

3.1.29**weighting**

pulse-repetition-frequency (PRF) dependent conversion (mostly reduction) of a peak-detected impulse voltage level to an indication that corresponds to the interference effect on radio reception

Note 1 to entry: For the analogue receiver, the psychophysical annoyance of the interference is a subjective quantity (audible or visual, usually not a certain number of misunderstandings of a spoken text).

Note 2 to entry: For the digital receiver, the interference effect is an objective quantity that may be defined by the critical bit error ratio (BER) or bit error probability (BEP) for which perfect error correction can still occur or by another, objective and reproducible parameter.

3.1.29.1

weighted disturbance measurement

measurement of disturbance using a weighting detector

3.1.29.2

weighting characteristic

peak voltage level as a function of PRF for a constant effect on a specific radiocommunication system, i.e. the disturbance is weighted by the radiocommunication system itself

3.1.29.3

weighting detector

detector that provides an agreed weighting function

3.1.29.4

weighting factor

value of the weighting function relative to a reference PRF or relative to the peak value

Note 1 to entry: The weighting factor is expressed in dB.

3.1.29.5

weighting function

weighting curve

relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector, i.e. the curve of response of a measuring receiver to repeated pulses

3.2 Abbreviations

The following abbreviations, not already provided in 3.1, are used in this standard.

CCM	Converted common mode
CM	Common mode
CMAD	Common mode absorption device
CVP	Capacitive voltage probe
CW	Continuous wave
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
FFT	Fast Fourier transform
IF	Intermediate frequency
ISM	Industrial, scientific and medical
LCL	Longitudinal conversion loss
OATS	Open area test site
PE	Protective earth
PRF	Pulse-repetition frequency
RC	Resistor-capacitor

RF	Radio frequency
SOLT	Short-open-load-through (calibration method)
VDF	Voltage division factor
VDU	Video display unit

4 Types of disturbance to be measured

4.1 General

Clause 4 describes the classification of different types of disturbance and the detectors appropriate for their measurement.

4.2 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 has 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 described in 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 16-1-1.

4.3 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) an r.m.s.-average detector provided for the weighted measurement of broadband disturbance for the assessment of the effect of impulsive disturbance to digital radio communication services but also useable for narrowband disturbance;
- d) a peak detector which may be used for either broadband or narrowband disturbance measurement.

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

5 Connection of measuring equipment

5.1 General

Clause 5 describes the connection of measuring equipment, measuring receivers and ancillary equipment such as artificial networks (AN) and voltage and current probes.

5.2 Connection of ancillary equipment

The connecting cable between the measuring receiver and the ancillary equipment shall be shielded and its characteristic impedance shall be matched to the input impedance of the measuring receiver. The measurement result shall account for the attenuation of the connecting cable.

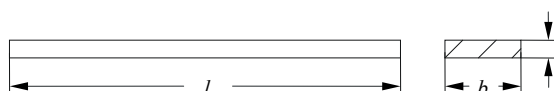
The output of the ancillary equipment shall be terminated with the prescribed impedance. A minimum attenuation of 10 dB between the AN output and the measuring receiver input is required in order to fulfill the specified tolerance of the AN impedance at its EUT port. This attenuation may be incorporated in the AN. The use of a transient limiter is recommended for the protection of the receiver input circuits. It shall be designed to provide signals of maximum receiver input level without creating nonlinear effects.

5.3 Connections to RF reference ground

The artificial network (AN) shall be connected to the reference ground by a low RF impedance, e.g. by direct bonding of the case of the AN to the reference ground of a shielded room, or with a low impedance conductor as short and as wide as practical (the maximum length to width ratio of which is 3:1, and the inductance of which is less than approximately 50 nH corresponding to an impedance of less than approximately 10 Ω at 30 MHz). An in situ test of the voltage division factor as explained in Annex E is recommended. This will help to find, e.g. a ground strap resonance in the AN grounding.

NOTE 1 A conductor with rectangular cross section (see drawing below) with: length $l = 30$ cm, width $b = 3$ cm, thickness $c = 0,02$ cm will cause an inductance L of approximately 210 nH ($X_L = 40$ Ω at 30 MHz), which is excessive. The value of L was calculated using the following equation:

$$L = 2l \left(\ln \frac{2l}{b+c} + 0,5 + 0,22 \frac{b+c}{l} \right)$$



where

L is the inductance of the conductor in nH

l, b, c are the dimensions of the conductor in cm

If such a length cannot be avoided, a width as large as possible will minimize the inductance.

Terminal voltage measurements shall be referenced only to the reference ground. Ground loops (common impedance coupling) shall be avoided. Ground loops will negatively affect repeatability of measurement and can, e.g. be detected if grounded components of a test set-up are touch-sensitive. This should also be observed for measuring apparatus (e.g. measuring receivers and connected ancillary equipment, such as oscilloscopes, analyzers, recorders, etc.) fitted with a protective earth conductor (PE) of safety class I equipment. The measuring instrumentation shall be provided with RF isolation so that the AN has only one RF connection to ground. This can be accomplished by RF chokes and isolation transformers, or by powering the measuring apparatus from batteries. Figure 1 shows an example of a recommended test set-up with three AMNs and PE chokes for the avoidance of ground loops. In this figure, also the receiver RF connecting cable to the AMN can act as a ground

connection if the receiver is grounded. Therefore, either a PE choke is needed at the receiver power input, or, if the receiver is outside a shielded room, a sheath current suppressor is needed on the connecting cable. Each AMN is thus RF-grounded only once.

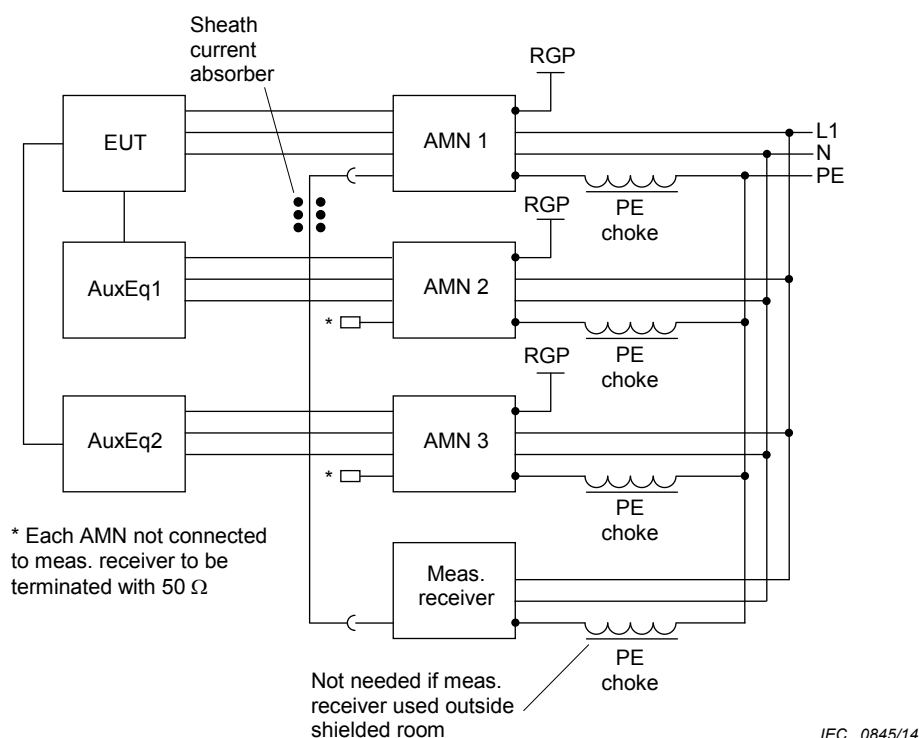


Figure 1 – Example of a recommended test set-up with PE chokes with three AMNs and a sheath current absorber on the RF cable

For safety reasons, PE chokes shall exhibit a low impedance for the power supply voltage at the power frequency and voltage in case of any defect. The short-circuit voltage across the PE choke shall be below 4 V. PE chokes may be incorporated inside the AMN.

The RF impedance of PE chokes and sheath current absorbers in the measurement frequency range should be high compared with the impedance of the AMN connection to the RGP. Commercially available PE chokes have, e.g. an inductance of 1,6 mH at nominal currents up to 36 A but they are not standardized in CISPR 16-1-2. The attenuation can be tested in accordance with Annex E. Some AMNs are available with built-in PE chokes. The difference in potential between PE and RGP shall be minimized to avoid saturation of PE chokes from the resulting DC or low frequency current flowing through the chokes. If the current is unknown, it may have to be measured.

NOTE 2 Sheath currents are RF currents flowing on the shield of shielded (e.g. coaxial) cables, and are a source of measurement uncertainty. Sheath current absorbers serve the purpose of reducing these currents.

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

Stationary test configurations of the AMN 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).

5.4 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.

6 General measurement requirements and conditions

6.1 General

Radio disturbance measurements, within the uncertainties allowed by CISPR 16-4-2, shall be:

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

- a) existence of a sufficient signal-to-noise ratio at the desired measurement level, e.g. the level of the relevant disturbance limit;
- b) having a defined measuring set-up, termination and operating conditions of the EUT;
- c) in the case of voltage probe measurements on the supply mains, the probe shall have an impedance of 1,5 k Ω as specified in CISPR 16-1-2; for measurements on other circuits, the impedance may need to be increased (as provided by active voltage probes) to avoid excessive loading of high impedance circuits;
- d) in the case of current probe measurements, the probe shall have an impedance in the measuring circuit of 1 Ω maximum, as specified in CISPR 16-1-2.

6.2 Disturbance not produced by the equipment under test

6.2.1 General

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

6.2.2 Compliance testing

A test site shall permit emissions from the EUT to be distinguished from ambient noise. The ambient noise level should be at least 20 dB below the specified limit. For in situ tests the ambient noise level should be at least 6 dB below the specified limit. In in situ cases, the disturbance plus ambient shall not exceed the limit. If the disturbance plus ambient exceeds the limit, then other methods need to be applied, for example, reduce the bandwidth, apply ambient cancellation, change frequency, etc. The suitability of the site for the permitted ambient level may be determined by measuring the ambient noise level with the EUT in place but not operating.

NOTE Annex A of CISPR 16-2-3:2010 [3] provides recommendations for measurement of disturbances in the presence of ambient emissions.

6.3 Measurement of continuous disturbance

6.3.1 Narrowband continuous disturbance

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

6.3.2 Broadband continuous disturbance

For the assessment of broadband continuous disturbance the level of which is fluctuating, the maximum reproducible measurement value shall be found; see 6.5.1 for further details.

6.3.3 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 shall 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.

6.4 EUT arrangement and measurement conditions

6.4.1 EUT arrangement

6.4.1.1 General

Where not specified in the product standard, the EUT shall be configured as described in the following paragraphs.

The EUT shall be installed, arranged and operated in a manner consistent with typical applications. Where the manufacturer has specified or recommended an installation practice, such practice shall be used in the test arrangement, where possible. This arrangement shall be typical of the normal installation practice. Interface cables, loads and devices shall be connected to at least one of each type of interface port of the EUT, and where practical, each cable shall be terminated in a device typical of actual usage.

Where there are multiple interface ports of the same type, additional interconnecting cables, loads and devices may need to be added to the EUT depending upon the results of preliminary tests. The number of additional cables or wires of the same type should be limited to the condition where the addition of another cable or wire does not significantly affect the disturbance level, i.e. varies by less than 2 dB, provided that the EUT remains compliant. The rationale for the selection of the configuration and loading of ports shall be included in the test report.

Interconnecting cables should be of the type and length specified in the individual equipment requirements. If the length can be varied, the length shall be selected to produce maximum disturbance.

If shielded or special cables are used during the tests to achieve compliance, a note shall be included in the instruction manual advising of the need to use such cables.

Excess lengths of cables shall be bundled at the approximate centre of the cable with the bundles 30 cm to 40 cm in length. If it is impractical to do so because of cable bulk or stiffness, the disposition of the excess cable shall be precisely noted in the test report.

Where there are multiple interface ports all of the same type, connecting a cable to just one of that type of port is sufficient, provided it can be shown that the additional cables would not significantly affect the results.

Any set of results shall be accompanied by a complete description of the cable and equipment orientation so that results can be reproduced. If specific conditions of use are required to meet the limits, those conditions shall be specified and documented, for example cable length, cable type, shielding and grounding. These conditions shall be included in the instructions to the user.

Equipment that is populated with multiple modules (such as drawers and plug-in cards) shall be tested with a mix and number representative of that used in a typical installation. The number of additional boards or plug-in cards of the same type should be limited to the condition where the addition of another board or plug-in card does not significantly affect the disturbance level, i.e. varies by less than 2 dB, provided that the EUT remains compliant. The

rationale used for selecting the number and type of modules should be stated in the test report.

A system that consists of a number of separate units shall be configured to form a minimum representative configuration. The number and mix of units included in the test configuration shall normally be representative of that used in a typical installation. The rationale used for selecting units should be stated in the test report.

One module of each type shall be operational in each equipment evaluated in an EUT. For an EUT comprising a system, one of each type of equipment that can be included in the possible system configuration shall be included in the EUT.

The results of an evaluation of EUTs having one of each type of module can be applied to configurations having more than one of each of those modules.

NOTE It has been found that disturbances from identical modules are generally not additive in practice.

The EUT position relative to the RGP shall be equivalent to that occurring in use. Therefore, floor-standing equipment is placed on, but insulated from, an RGP, and tabletop equipment is placed on a non-conductive table.

Equipment designed for wall-mounted operation shall be tested as tabletop EUT. The orientation of the equipment shall be consistent with normal installation practice.

Combinations of the equipment types identified above shall also be arranged in a manner consistent with normal installation practice. Equipment designed for both tabletop and floor standing operation shall be tested as tabletop equipment unless the usual installation is floor standing, then that arrangement shall be used.

The ends of signal cables attached to the EUT that are not connected to another unit or auxiliary equipment (AuxEq) shall be terminated using the correct terminating impedance defined in the product standard. If no product standard can be applied to the particular configuration, the termination shall be defined by the EUT manufacturer and noted in the test report.

Cables or other connections to auxiliary equipment located outside the test site shall drape to the floor, and then be routed to the place where they leave the test site.

Installation of AuxEq shall be in accordance with normal installation practice. Where this means that the AuxEq is located on the test site, it shall be arranged using the same conditions applicable for the EUT (for example, distance from the ground plane and insulation from the ground plane if floor standing, layout of cabling).

6.4.1.2 Arrangement of tabletop equipment

Equipment intended for tabletop use shall be placed on a non-conductive table. The size of the table will nominally be 1,5 m by 1,0 m but may ultimately be dependent on the horizontal dimensions of the EUT.

Intra-unit cables shall be draped over the back of the table. If a cable hangs closer than 0,4 m from the horizontal ground plane (or floor), the excess shall be folded at the cable centre into a bundle no longer than 0,4 m, such that the part of the bundle closest to the horizontal RGP is at least 0,4 m above the plane.

Cables shall be positioned as for normal usage.

If the mains port input cable is less than 0,8 m long (including power supplies integrated in the mains plug), an extension cable shall be used such that the external power supply is

placed on the tabletop. The extension cable shall have characteristics similar to the mains cable (including the number of conductors and the presence of a ground connection). The extension cable shall be treated as part of the mains cable.

In the above arrangements, the cable between the EUT and the power accessory shall be arranged on the tabletop in the same manner as other cables connecting components of the EUT.

6.4.1.3 Arrangement of floor-standing equipment

The EUT shall be placed on the horizontal RGP, orientated for normal use, but separated from metallic contact with the RGP by up to 15 cm of insulation.

The cables shall be insulated (by up to 15 cm) from the horizontal RGP. If the equipment requires a dedicated ground connection, then this shall be provided and bonded to the horizontal RGP.

Intra-unit cables (between units forming the EUT or between the EUT and any auxiliary equipment) shall drape to, but remain insulated from, the horizontal RGP. Any excess cable shall either be folded at the cable centre into a bundle no longer than 0,4 m or arranged in a serpentine fashion. If an intra-unit cable length is not long enough to drape to the horizontal RGP but drapes closer than 0,4 m, then the excess shall be folded at the cable centre into a bundle no longer than 0,4 m. The bundle shall be positioned such that it is either 0,4 m above the horizontal RGP or at the height of the cable entry or connection point if this is within 0,4 m of the horizontal RGP.

For equipment with a vertical cable riser, the number of risers shall be typical of installation practice. Where the riser is made of non-conductive material, a minimum spacing of at least 0,2 m shall be maintained between the closest part of the equipment and the nearest vertical cable. Where the riser structure is conductive, the minimum spacing of 0,2 m shall be between the closest parts of the equipment and riser structure.

6.4.1.4 Arrangement for combinations of tabletop and floor-standing equipment

Intra-unit cables between a tabletop unit and a floor-standing unit shall have the excess cable folded into a bundle no longer than 0,4 m. The bundle shall be positioned such that it is either 0,4 m above the horizontal RGP or at the height of the cable entry or connection point if this is within 0,4 m of the horizontal RGP.

6.4.2 Normal load conditions

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

6.4.3 Duration of operation

The duration of operation (during which the disturbance can be measured) 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.

6.4.4 Running-in/warm-up time

No specific running-in/warm-up 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 (e.g. operating temperature is reached, software loading is completed and EUT is ready to perform its intended operation) are typical of those during the life of the equipment. The term "running-in time" relates to EUTs that include electrical motors. For some EUTs, special test conditions may be prescribed in the relevant product publications.

6.4.5 Supply

The EUT shall be operated from a supply having the rated voltage of the EUT. EUTs with more than one rated voltage shall be tested at the rated voltage which causes maximum disturbance. Product standards may call out additional measurements, if, for example, the levels of disturbances vary considerably with the supply voltage.

6.4.6 Mode of operation

The EUT shall be operated under conditions of use intended by the manufacturer which cause the maximum disturbance at the measurement frequency.

6.4.7 Operation of multifunction equipment

Multifunction equipment that is subjected simultaneously to different clauses of a product standard and/or different standards shall be tested with each function operated in isolation, if this can be achieved without modifying the equipment internally. The equipment thus tested shall be deemed to have complied with the requirements of all clauses/standards when each function has satisfied the requirements of the relevant clause/standard.

For equipment that it is not practical to test with each function operated in isolation, or where the isolation of a particular function would result in the equipment being unable to fulfil its primary function, or where the simultaneous operation of several functions would result in saving measurement time, the equipment shall be deemed to have complied if it meets the provisions of the relevant clause/standard with the necessary functions operated.

6.4.8 Determination of EUT arrangement(s) that maximize(s) emissions

Initial testing shall identify the frequency that has the highest disturbance relative to the limit. This identification shall be performed whilst operating the EUT in typical modes of operation and with cable positions in a test arrangement that is representative of typical installation practice.

The frequency of highest disturbance with respect to the limit shall be found by investigating disturbances at a number of significant frequencies. This provides confidence that the probable frequency of maximum disturbance has been found and that the associated cable, EUT arrangement and mode of operation have been identified.

For initial testing, the EUT should be arranged in accordance with the product standards as appropriate.

6.4.9 Recording of measurement results

Of those disturbances above ($L - 20$ dB), where L is the limit level in dB(μ V) or dB(μ A), the disturbance levels and the frequencies of at least the six disturbances having the smallest margin to the limit L shall be recorded.

In addition, the test report shall include the value of the measurement instrumentation uncertainty corresponding to the used test set-up, calculated as per the requirements of CISPR 16-4-2.

6.5 Interpretation of measuring results

6.5.1 Continuous disturbance

The following steps shall be applied when interpreting the results for continuous disturbance measurements:

- a) At each frequency for which the level of disturbance is close to the limit and not steady, the reading on the measuring receiver is observed for at least 15 s for each measurement; the highest readings shall be recorded. Some product standards allow the exclusion of isolated clicks, which shall be ignored (e.g. 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;
 - 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.

6.5.2 Discontinuous disturbance

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

6.5.3 Measurement of the duration of disturbances

The duration of a disturbance shall be known in order to measure it correctly and to determine if it is discontinuous. The duration of a disturbance may be measured in one of the following ways:

- through the connection of an oscilloscope to a measuring receiver's IF output to allow monitoring of the disturbance in the time-domain;
- through the tuning of either an EMI receiver or a spectrum analyzer to the disturbance frequency without frequency scanning (i.e. 'zero-span' mode) to allow monitoring of the disturbance in the time-domain; or
- through the use of the time-domain output of an FFT-based measuring receiver.

Guidance for the determination of the appropriate measurement time can be found in 8.3.

6.6 Measurement times and scan rates for continuous disturbance

6.6.1 General

For manual and automated or semi-automated measurements, measurement times and scan rates of measuring and scanning receivers shall be set such that the maximum emissions are measured. Especially, where a peak detector is used for prescans, the measurement times and scan rates have to take the timing of the disturbance under test into account. More detailed guidance on the execution of automated measurements can be found in Clause 8.

6.6.2 Minimum measurement times

The minimum measurement (dwell) times are given in Table 2. The minimum measurement (dwell) times for scanning receivers and FFT-based measuring instruments in Table 2 and the scan times for spectrum analyzers in Table 1 apply to CW signals. The minimum scan times of Table 1 were derived to perform measurements in the entire CISPR band.

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 to 150 kHz	14,1 s	2 820 s = 47 min
B	0,15 MHz to 30 MHz	2,985 s	5 970 s = 99,5 min = 1 h 39 min
C and D	30 MHz to 1 000 MHz	0,97 s	19 400 s = 323,3 min = 5 h 23 min

Table 2 – Minimum measurement times for the four CISPR bands

Frequency band		Minimum measurement time T_m
A	9 kHz to 150 kHz	10,00 ms
B	0,15 MHz to 30 MHz	0,50 ms
C and D	30 MHz to 1 000 MHz	0,06 ms
E	1 GHz to 18 GHz	0,01 ms

Depending on the type of disturbance, the scan time may have to be increased, especially for swept 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 disturbance is not steady (see 6.5.1).

Scan rates and measurement times for use with the average detector will be found in Annex D.

Most product standards call out for quasi-peak detection for compliance measurements which is very time consuming, if no time-saving procedures are applied (see Clause 8). Before time-saving procedures can be applied, the disturbance is detected in a prescan. To ensure that e.g. intermittent signals are not overlooked during an automatic scan, the considerations in 6.6.3 to 6.6.5 need to be taken into account.

6.6.3 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:

- for a single sweep: the measurement time at each frequency shall be larger than the intervals between pulses for intermittent signals;
- 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 video bandwidth settings. 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 as defined below 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 of 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 is 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:

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

where

$T_{s\min}$ is the minimum sweep time

Δf is the frequency span

B_{res} is the resolution bandwidth

k is the 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.

NOTE Actual values of k are available from instrument manufacturers. The actual values are normally taken into consideration in the coupled mode of the receiver or spectrum analyzer firmware.

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:

$$T_{s\min} = (k \times \Delta f) / (B_{\text{res}} \times B_{\text{video}}) \quad (2)$$

where B_{video} is the 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 overwritten 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.).

6.6.4 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 % or less of the resolution bandwidth used (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:

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

where $T_{m\min}$ is the minimum measurement (dwell) time at each frequency.

In addition to the measurement time, some time is needed 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.

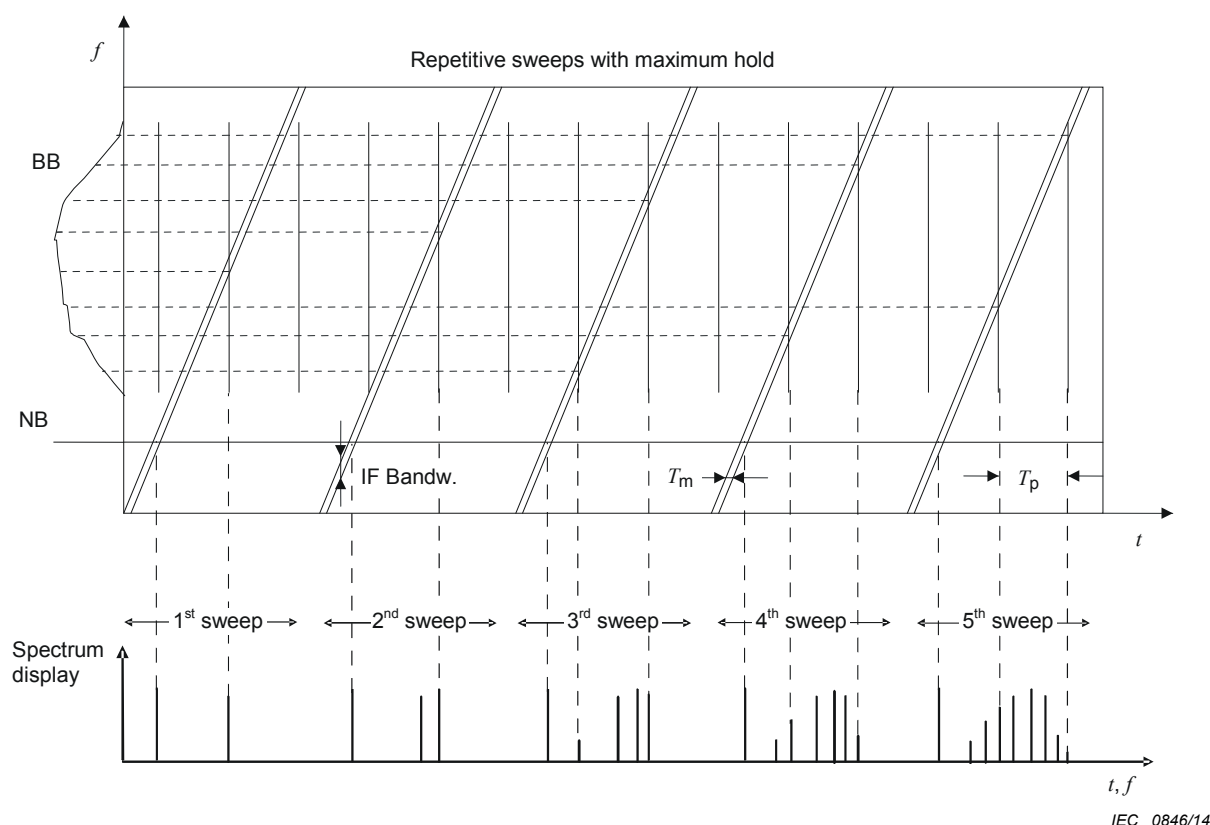
For purely broadband emissions, the frequency step size may be increased. In this case the objective is to find the maxima of the disturbance spectrum only.

6.6.5 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 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 elements, 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 shall 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 2, 3, 4 and 5 show examples of the relationship between various time-varying disturbance spectra and the corresponding display on a measuring receiver. In the cases of Figures 2, 4, and 5, the upper part of the figure shows the position of the receiver bandwidth as it either sweeps or steps through the spectrum.



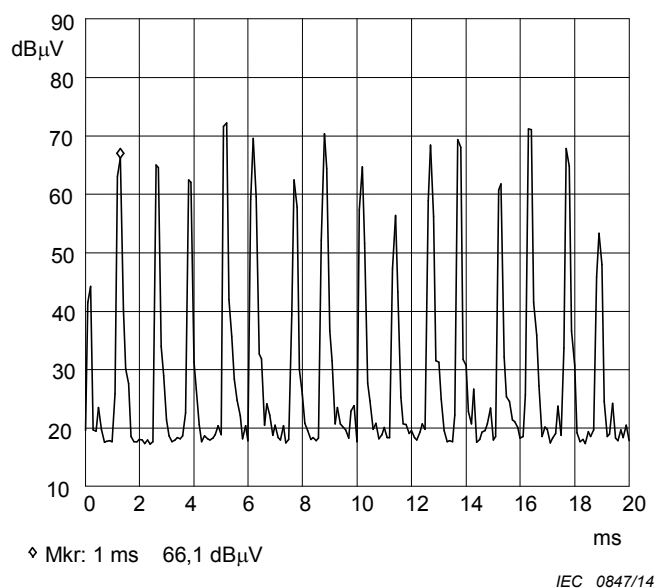
T_p is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum-versus-time display (upper part of the figure).

Figure 2 – Measurement of a combination of a CW signal (“NB”) and an impulsive signal (“BB”) using multiple sweeps with maximum hold

If the type of disturbance is unknown, multiple sweeps with the shortest possible sweep time and peak detection allow the spectrum envelope to be determined. 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 shown for example in Figure 3.



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

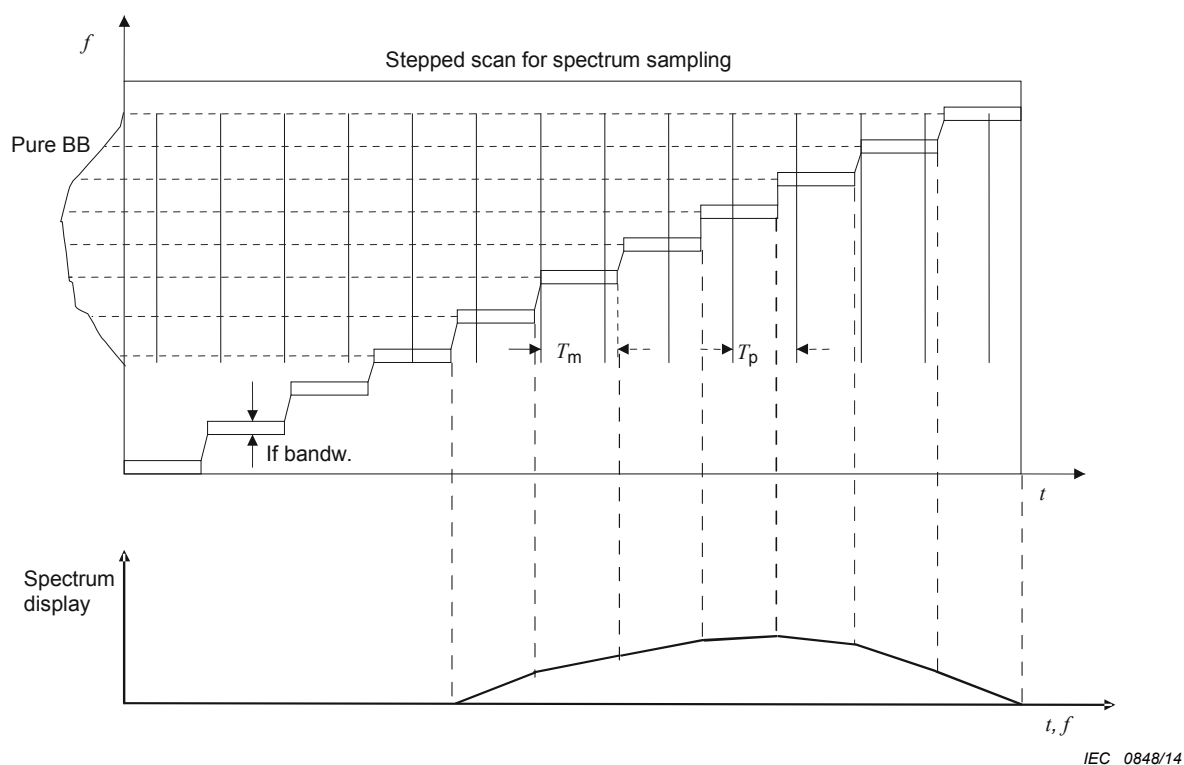
Figure 3 – Example of a timing analysis

From the timing analysis, 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 disturbance 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 4). The step size is 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 5) or a slow single sweep may be used. A timing analysis may be required prior to the actual measurement to ensure proper signal interception.

Intermittent broadband disturbances shall be measured with a disturbance analyzer that complies with CISPR 16-1-1. For explanation of related measurement procedures, see CISPR 14-1.

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



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 – A broadband spectrum measured with a stepped receiver

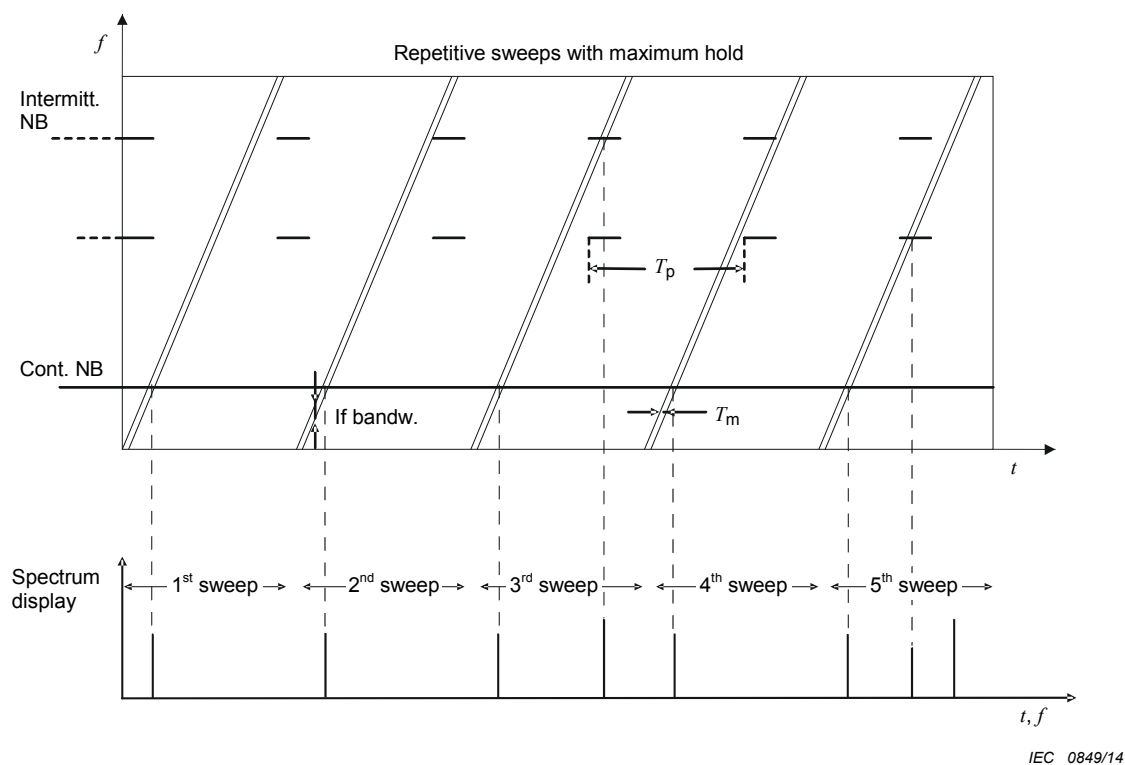


Figure 5 – Intermittent narrowband disturbances measured using fast short repetitive sweeps with maximum hold function to obtain an overview of the disturbance spectrum

6.6.6 Timing considerations using FFT-based instruments

FFT-based measuring instruments may combine the parallel calculation at N frequencies and a stepped scan. For this purpose, the frequency range of interest is subdivided into a number of segments N_{seg} that are scanned sequentially. The procedure is shown in Figure 6 for three segments. The total scan time for the frequency range of interest T_{scan} is calculated as:

$$T_{\text{scan}} = T_m N_{\text{seg}} \quad (4)$$

where

T_m is the measurement time for each segment, and
 N_{seg} is the number of segments.

FFT-based measuring instruments may also provide methods to improve the frequency resolution across a given frequency range. In general, an FFT-based measuring instrument will have a fixed frequency step $f_{\text{step FFT}}$ that is determined by the number of frequencies of the FFT. Increased frequency resolution is achieved by performing repeat calculations over a given frequency range. For each repeat calculation, the lowest frequency is incremented by a step ratio, $f_{\text{step final}}$.

Hence the first calculation over the given frequency range considers the following frequencies:

f_{min} ,
 $f_{\text{min}} + f_{\text{step FFT}}$,
 $f_{\text{min}} + 2f_{\text{step FFT}}$,
 $f_{\text{min}} + 3f_{\text{step FFT}} \dots$

The second calculation over the given frequency range considers the following frequencies:

$f_{\text{min}} + f_{\text{step final}}$,
 $f_{\text{min}} + f_{\text{step final}} + f_{\text{step FFT}}$,
 $f_{\text{min}} + f_{\text{step final}} + 2f_{\text{step FFT}}$,
 $f_{\text{min}} + f_{\text{step final}} + 3f_{\text{step FFT}} \dots$

This procedure, applied for a step ratio of 3, is displayed in Figure 7.

The scan time T_{scan} is calculated as:

$$T_{\text{scan}} = T_m \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \quad (5)$$

where

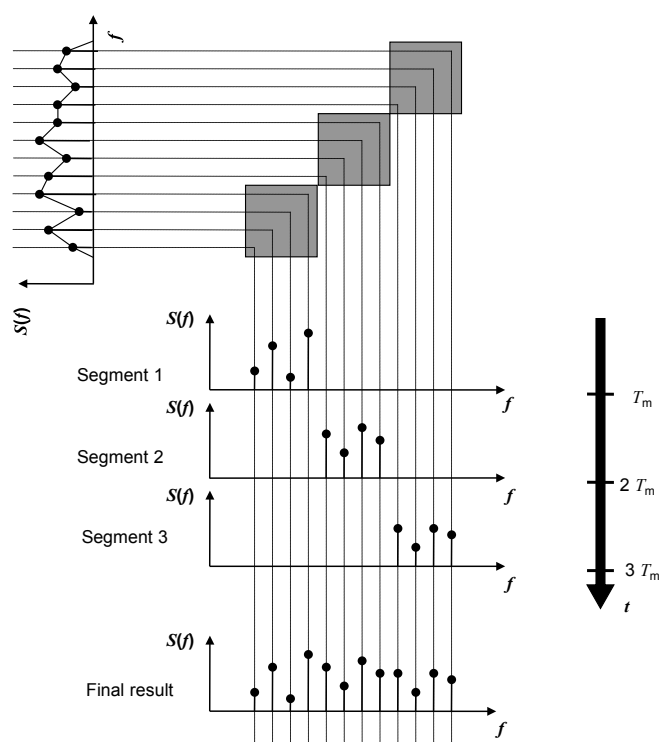
T_m is the measurement time, and
 $\frac{f_{\text{step FFT}}}{f_{\text{step final}}}$ is the step ratio.

For a system that combines both methods, the scan time T_{scan} is calculated as:

$$T_{\text{scan}} = T_m N_{\text{seg}} \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \quad (6)$$

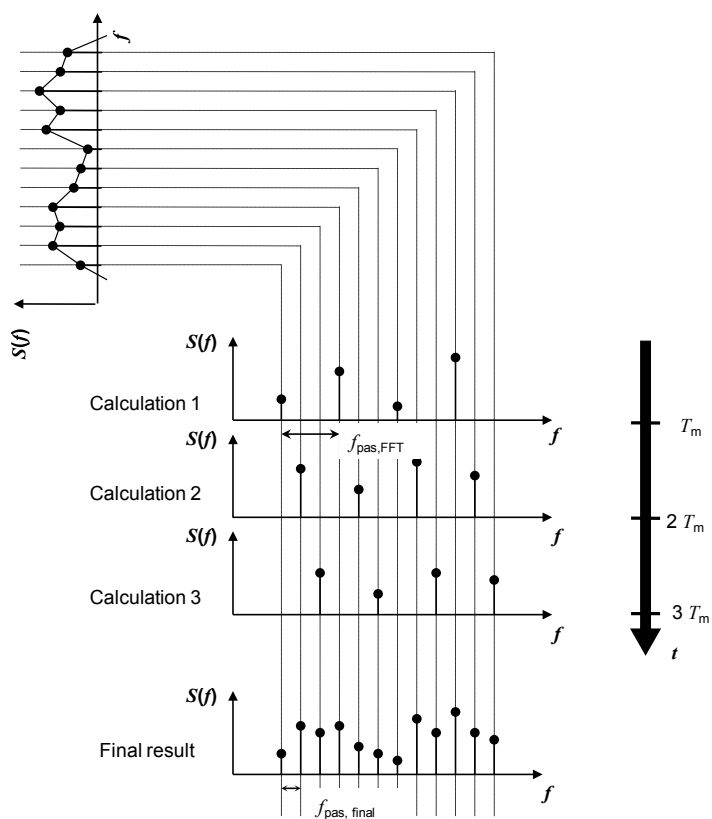
NOTE 1 FFT-based measuring instruments may combine both methods, i.e. the stepped scan as well as a method to improve the frequency resolution.

NOTE 2 Additional background information is provided in CISPR/TR 16-3 [4].



IEC 0850/14

Figure 6 – FFT scan in segments



IEC 0851/14

Figure 7 – Frequency resolution enhanced by FFT-based measuring instrument

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

7.1 General

When testing for compliance with disturbance 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 disturbance*: 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 disturbance, i.e.:
 - common mode (also called asymmetric mode, i.e. the vector sum of voltages/currents in bundle or group of wires);
 - differential mode (also called symmetric mode);
 - unsymmetric mode (voltage between terminal and reference ground).

NOTE The unsymmetric mode voltage is primarily measured at the power port. The common mode voltage (or current) is measured primarily at telecommunication, signal and control ports.

- b) *the measuring equipment*: the type of measuring equipment is chosen in relation to the disturbance properties to be determined (see 7.2);
- c) *the ancillary equipment*: the type of ancillary 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 7.1 a). Each type of ancillary equipment presents RF loading to the measured signals and ports (see 7.3);
- d) *RF load conditions of the disturbance source*: the test 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 7.3 and 7.4);
- e) *the test configuration of EUT*: a standardized test configuration shall specify the reference ground, the position of the EUT and ancillary measuring equipment with respect to that reference ground, connections to that reference ground and interconnections of the EUT with the associated equipment in an unambiguous way (see 7.4 and 7.5).

7.2 Measuring equipment (receivers, etc.)

7.2.1 General

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

7.2.2 Use of detectors for conducted disturbance measurements

CISPR 16-1-1 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 C provides guidance on how these measurements may be performed efficiently.

7.3 Ancillary measuring equipment

7.3.1 General

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

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

NOTE Some standards use the terms impedance stabilization network (ISN) for ANs for disturbance measurements on telecommunication ports (i.e. AANs or Y-networks).

- b) current measuring sensors, such as current probes.

7.3.2 Artificial networks (ANs)

7.3.2.1 General

The common mode, differential and unsymmetric mode impedances of actual networks, such as of power mains and telecommunication networks, are location dependent and, in general, time varying. Therefore, type testing of disturbance requires standardized impedance simulation networks, referred to as artificial networks (ANs). 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.

7.3.2.2 Types of artificial networks

The ANs specified in CISPR 16-1-2 shall be used, unless specific reasons call for another construction. In general three types of AN can be distinguished:

- a) *the V-type AN (typically used as V-AMN, or LISN)*: 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) the measurement of the vector sum of both the differential and common mode voltage. 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 (actually not used in product publications but could be used as delta-AMN for power lines or as delta-network for signal lines)*: 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 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 Y-type AN (also called the asymmetric artificial network, AAN, or ISN)*: 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 Y-type AN as such. The defined differential mode impedance shall then be provided by the external circuit connected to the supply (line) terminals of the Y-type AN. This type of AN is used to measure common mode disturbance voltages only.

7.3.3 Voltage probes

For specifications of voltage probes, see CISPR 16-1-2.

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 unsymmetric disturbance voltage. The probe presents a high RF impedance between the terminal to be measured and the reference ground.

The capacitive voltage probe (CVP) is used to measure the asymmetric (common mode) voltage of a number of conductors without making direct conductive contact. It is constructed so that it can be clamped around the conductors to be measured. Clamping the CVP around an individual conductor will allow the measurement of the unsymmetric disturbance voltage.

7.3.4 Current probes

Current probes or current transformers allow the measurement of all three types of disturbance current (see 7.1 and CISPR 16-1-2) 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.

The current probe cannot be used for the measurement of the converted common mode (CCM) current between an AAN and the EUT. The CCM shall only be measured by the voltage at the output of the AAN (see 7.3.2.2 c)).

For already defined (and standardized) current probes, see CISPR 16-1-2.

NOTE The purpose of the AAN is to simulate the disturbance potential of the network cabling that is attached to the telecommunication port of the EUT. Thus, in response to the differential-mode voltage launched onto the network at the telecommunication port of the EUT, the AAN generates an internal common-mode voltage that represents the converted common-mode (CCM) voltage that would be generated by the attached network cabling. This internally generated common-mode voltage has an associated common-mode current (I_{CCM} in Figure 8). This current undergoes current division within the AAN (into I_{CCM1} and I_{CCM2} in Figure 8). The current division is determined by the common mode impedance of the AAN output (Z_T on Figure 8) and the common mode impedance presented at the AAN's EUT terminal (Z_E in Figure 8). The common mode impedance of the AAN output is controlled and hence the common-mode voltage at the AAN output (V_{CCM} in Figure 8) is the measure of the disturbance potential of the connected network. The common mode impedance presented at the AAN's EUT port is not controlled: rather, it varies with frequency and depends upon the EUT size and the EUT arrangement. Hence this CCM current (I_{CCM2} in Figure 8) cannot be measured with a current probe because, for IT equipment of typical size, the magnitude of Z_E varies from around 2 k Ω to around 200 Ω , in the frequency range from 150 kHz to 30 MHz.

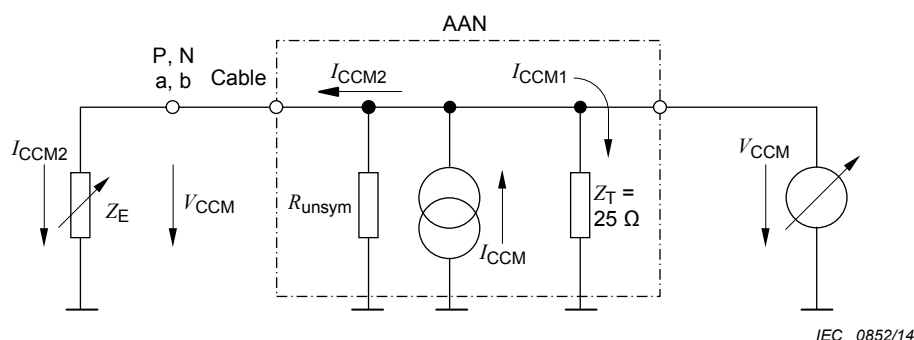


Figure 8 – Illustration of current I_{CCM}

7.4 Equipment under test configuration

7.4.1 Arrangement of the EUT and its connection to the AN

For measurement of the disturbance voltage, the EUT is connected to the power supply mains and any other extended network via one or more AN(s) (in general, the V-type network is used as an AMN for the power port, see Figure 9), in accordance with the following

requirements. CISPR product publications supply additional test details relevant to particular EUTs.

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 an RGP. This ground plane is normally the wall or floor of a shielded room. It may also be a grounded metal sheet with dimensions 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 ground plane;
- all other conductive surfaces of the EUT shall be more than 40 cm away from the RGP;
- the ANs are placed on the floor as shown in Figure 9 in such a way that one side of the AN housing is 40 cm from the vertical RGP and other metallic parts. V-networks (AMNs) and Y-networks (AANs) are shown in Figures 9 and 10.
- the EUT cable connections shall be as shown in Figure 9;
- the optional test configuration for table-top EUT with only a power cord attached is shown in Figure 11.

NOTE The configuration in Figure 11 may cause an ambiguity due to the fact that with some EUTs, the metallic disturbance source is not in the center of the nonmetallic housing (see CISPR 16-4-1 [5]).

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 which shall not make metallic contact with the floor support(s) of the EUT, but which shall make contact with intentional ground conductors of the EUT. The metal floor may be used as the RGP 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 12 and 13.

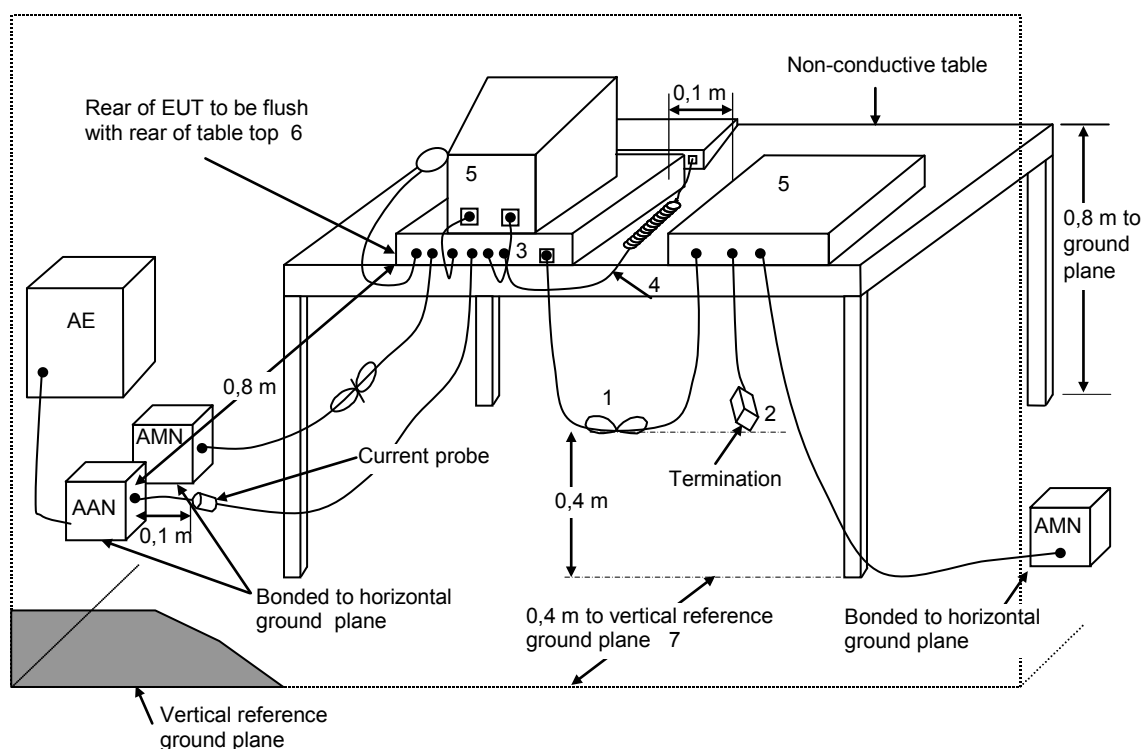
The AN is RF bonded to the RGP by a low RF impedance connection (as explained in 5.2). The "low" RF impedance value should preferably be less than 10 Ω at 30 MHz. This can, for example, be achieved if the housing of the AN is mounted directly to the RGP or its connection strap has a length-to-width ratio not more than 3:1. Resonances in the AN grounding can be identified by an in situ test of the voltage division factor (see Annex E).

The EUT is arranged as shown in Figures 9 through 13. The reference distance between the boundary of the EUT and the closest surface of the AN is 80 cm. A good approach for table-top EUTs as in Figures 9 and 13 is the AN mounted in the ground plane – the front panel being flush with the ground plane.

The power mains leads to an AN and the connecting cable from the network to the measuring receiver should 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 AN with a 1 m long lead or as specified in the relevant equipment documentation. The 1 m length is preferred as it gives a lower standard compliance uncertainty.

Unless the EUT has specific requirements for ground lead impedance, the following instructions shall apply. 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 it 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 between 30 cm and 40 cm in length, and arranged in the form of a non-inductive serpentine in such a way that the return

length of the lead does not exceed 1 m (see also Figure 14). However, when the bundled lead may influence the measurement results, a shortening of the length to 1 m is recommended.



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Key

- 1 Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth forming a bundle 40 cm long or less, hanging approximately in the middle between the ground plane and the table. The minimum bend radius of the cable shall not be exceeded. If the bend radius causes the bundle length to exceed 40 cm, the bend radius shall determine the bundle length.
- 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 – if possible.
- 3 The EUT is connected to one AMN. Measurement terminals of AMNs and AANs shall be terminated with 50 Ω if not connected to the measuring receiver. AMNs are placed directly on the horizontal ground plane 0,8 m from the EUT and 40 cm from vertical ground plane if the vertical ground plane is the RGP (see also Figure 10 a)). Alternatively (as shown in Figure 10 b)), AMNs are placed on the vertical ground plane 0,8 m from the EUT, if the horizontal ground plane is the RGP, which is 40 cm below the EUT. To reach the 0,8 m distance, the AMNs may have to be moved to the side. All auxiliary equipment is connected to a second AMN if this second AMN is capable of supplying the necessary power. In cases where a single AMN is not capable of supplying the necessary power, several AMNs may be used to supply the auxiliary equipment. AANs are used for unshielded twisted pair cables containing 1, 2, 3 or 4 pairs, and current probes may be used for other cables (unshielded or shielded).
- 4 Cables of hand-operated devices, such as keyboards, mice, 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 at a distance of 40 cm from a vertical conducting plane that is bonded to the floor ground plane.

Tolerances of cable lengths and distances are as practical as possible.

Figure 9 – Test configuration: table-top equipment for conducted disturbance measurements on power mains

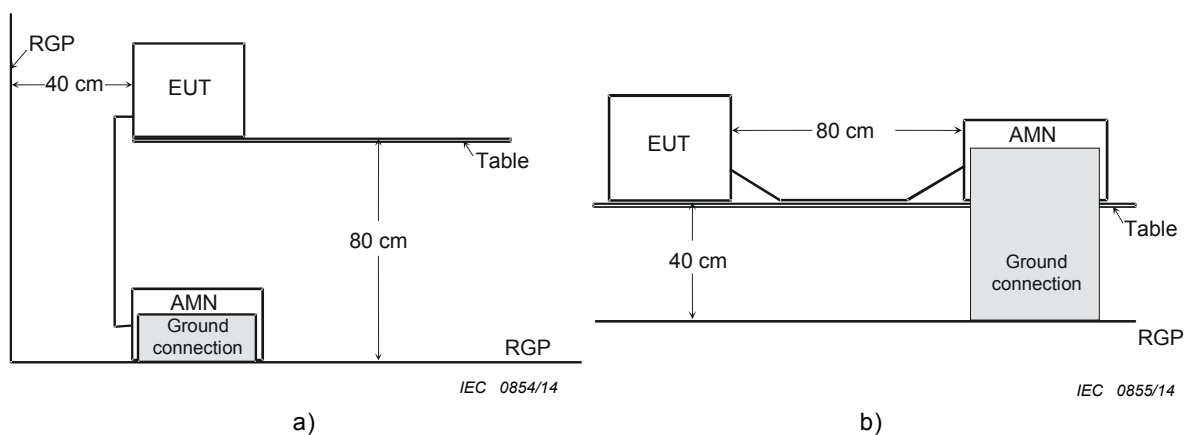
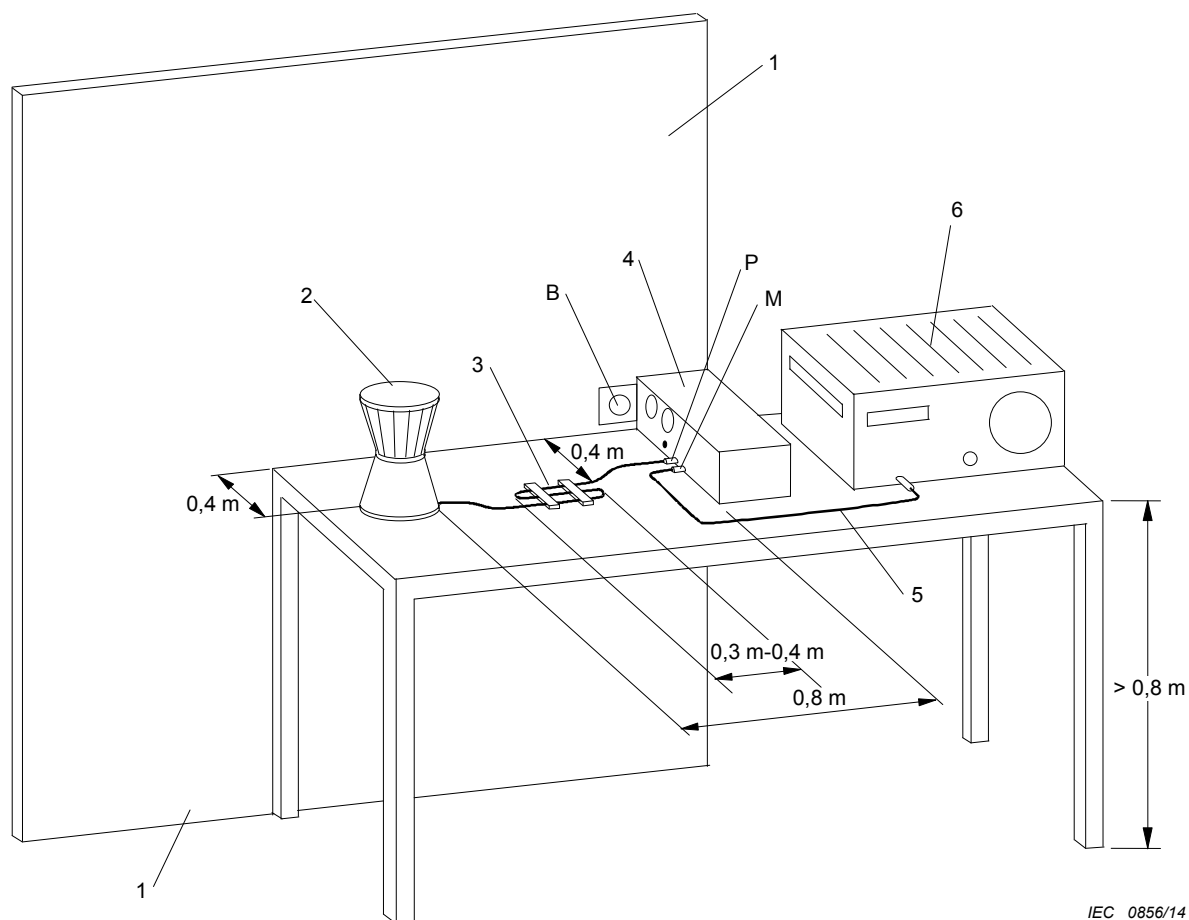


**Figure 10 – Arrangement of EUT and AMN at 40 cm distance, with
a) vertical RGP and b) horizontal RGP**

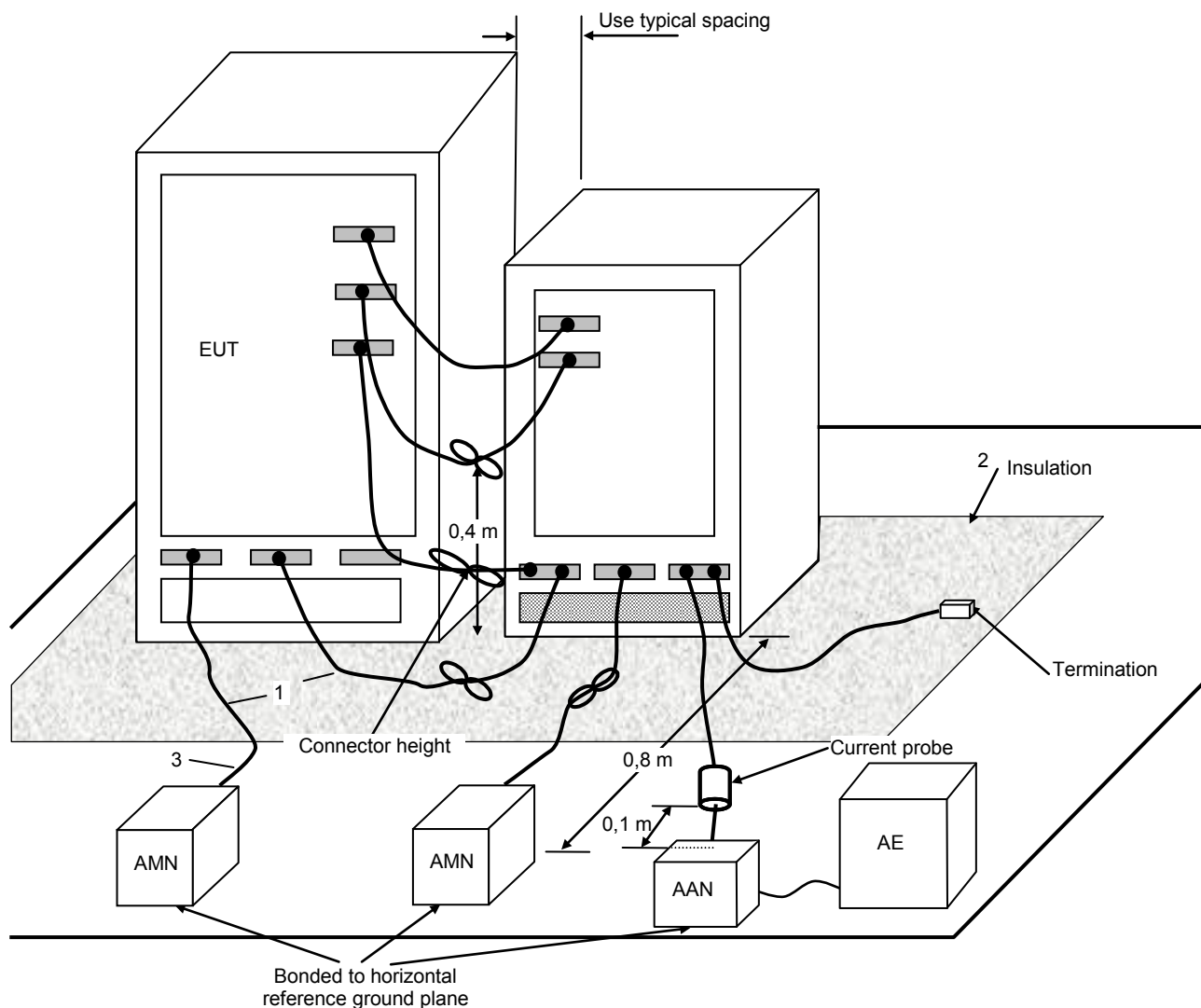


Key

- 1 Metallic wall 2 m by 2 m
- 2 EUT
- 3 Excess power cord (e.g. 0,02 m by 0,3 m forming a meander)
- 4 AMN
- 5 Coaxial cable
- 6 Measuring receiver
- B Reference ground connection
- M Measuring receiver port
- P Power to EUT

Tolerances of cable lengths and distances are as practical as possible.

**Figure 11 – Optional example test configuration for an EUT
with only a power cord attached**

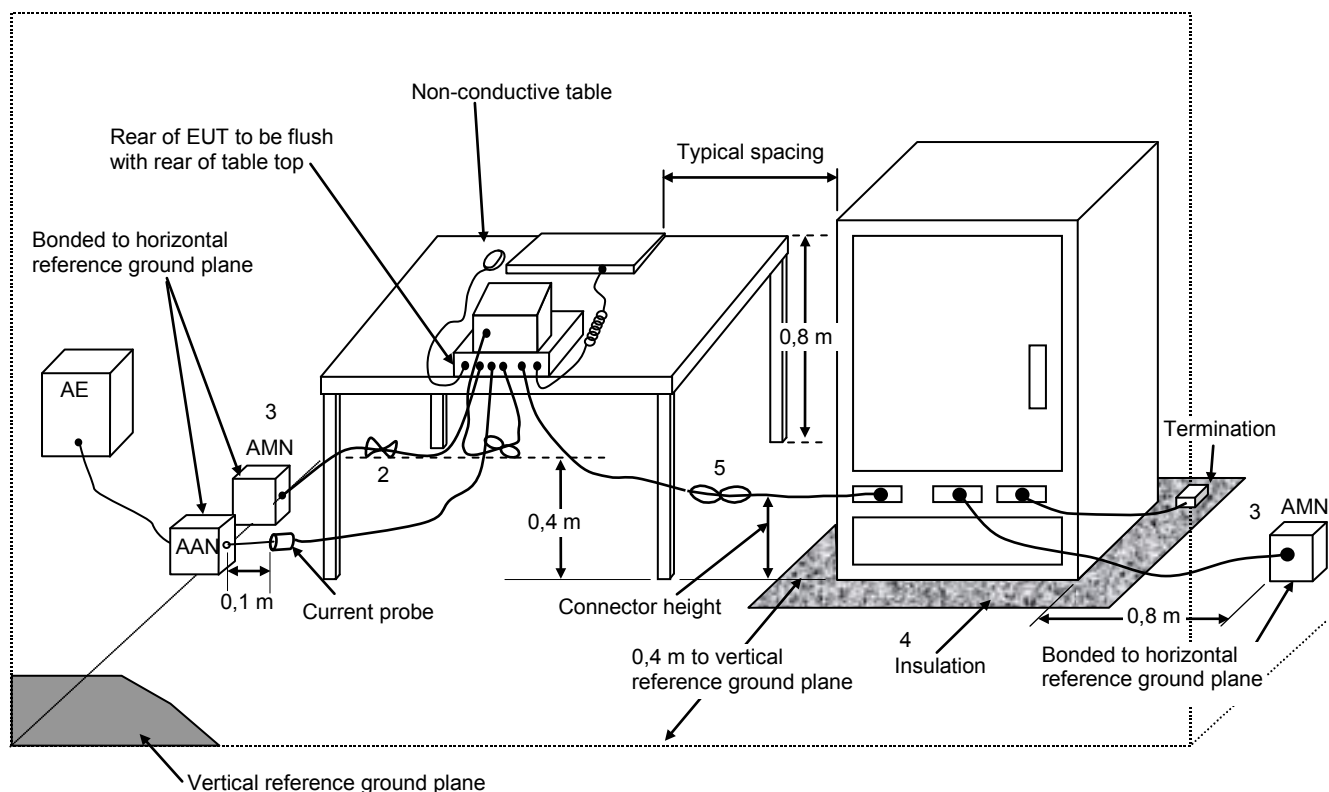


IEC 0857/14

Key

- 1 Excess cables shall be bundled in the centre or shortened to appropriate length.
 - 2 The EUT and cables shall be insulated (up to 15 cm) 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. Refer also to comment 3 in Figure 9.
- Tolerances of cable lengths and distances are as practical as possible.

Figure 12 – Test configuration: floor-standing equipment (see 7.4.1 and 7.5.2.3)



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Key

- 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 to 40 cm long or less, 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. To reach the 0,8 m distance, the AMNs may have to be moved to the side. Refer also to comment 3 in Figure 9.
- 4 The EUT and the cables shall be insulated (up to 15 cm) 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.

Tolerances of cable lengths and distances are as practical as possible.

**Figure 13 – Example test configuration: floor-standing and table-top equipment
(see 7.4.1 and 7.5.2.3)**

7.4.2 Procedure for the measurement of unsymmetric disturbance voltages with V-networks (AMNs)

7.4.2.1 General

Generally, the measurement of disturbance voltages using ANs is the preferred CISPR measurement method. If, e.g. an AMN causes the EUT not to work, then measurements with current probes or voltage probes should be made.

7.4.2.2 Arrangement 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 disturbance voltage of the individual mains lead is measured with reference to the reference metal wall (general ground of the measuring equipment) to which the housing of the

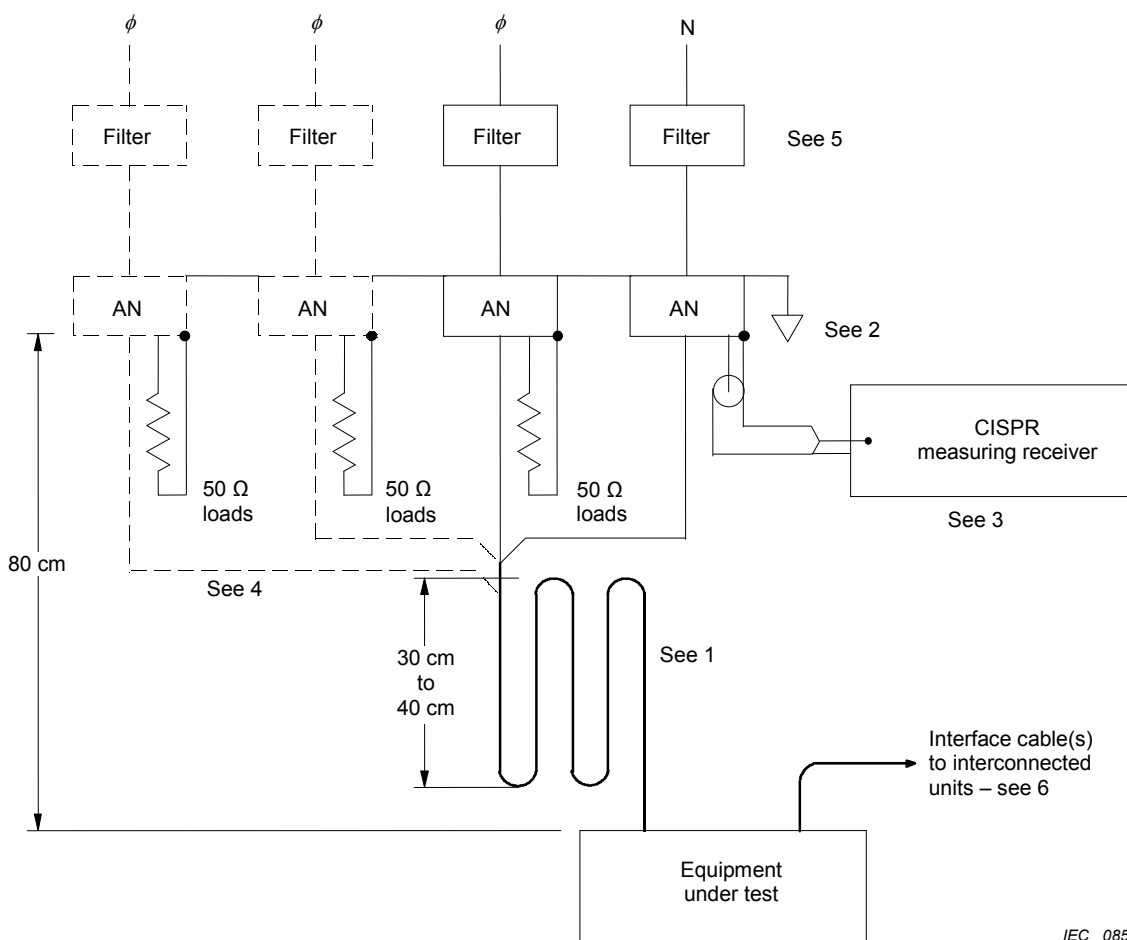
equipment under test is connected via its protective ground conductor and the ground connection of the artificial mains network (see the equivalent circuit in Figure 15).

The parameters determining the interference potential of grounded test units are discussed in 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 7.5 on measurement in systems).

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 ground, and moreover, because safety conductors need not be used on every product per IEC 60364-4 [8], disturbance voltage measurements on pluggable safety-class I appliances shall be carried out according to 7.4.2.3, 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 a PE 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).

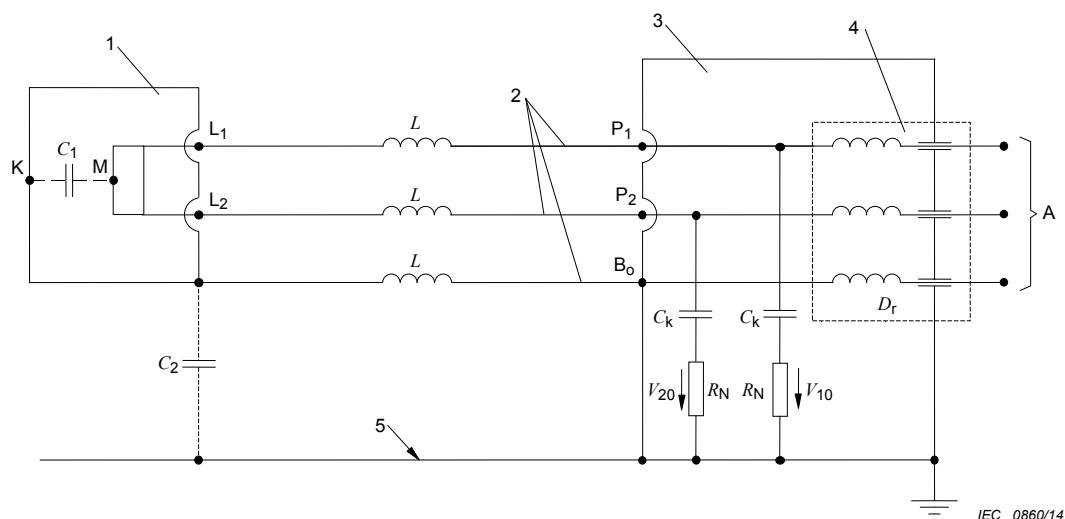


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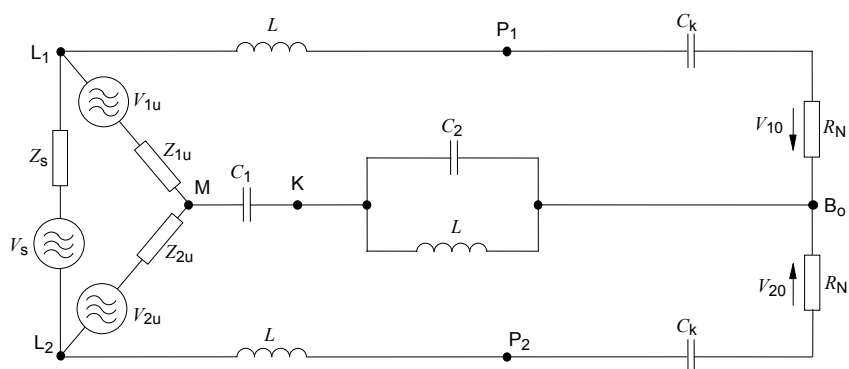
Key

- 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 3:1.
- 3 The CISPR measuring receiver shall be isolated from the AMN using a sheath current absorber on the coaxial cable (example in E.2).
- 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 shall 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 14 – Schematic of disturbance voltage measurement configuration
(see also 7.5.2.3)**



a) Schematic for measurement and power circuit



b) Equivalent voltage source and measurement circuit

Key

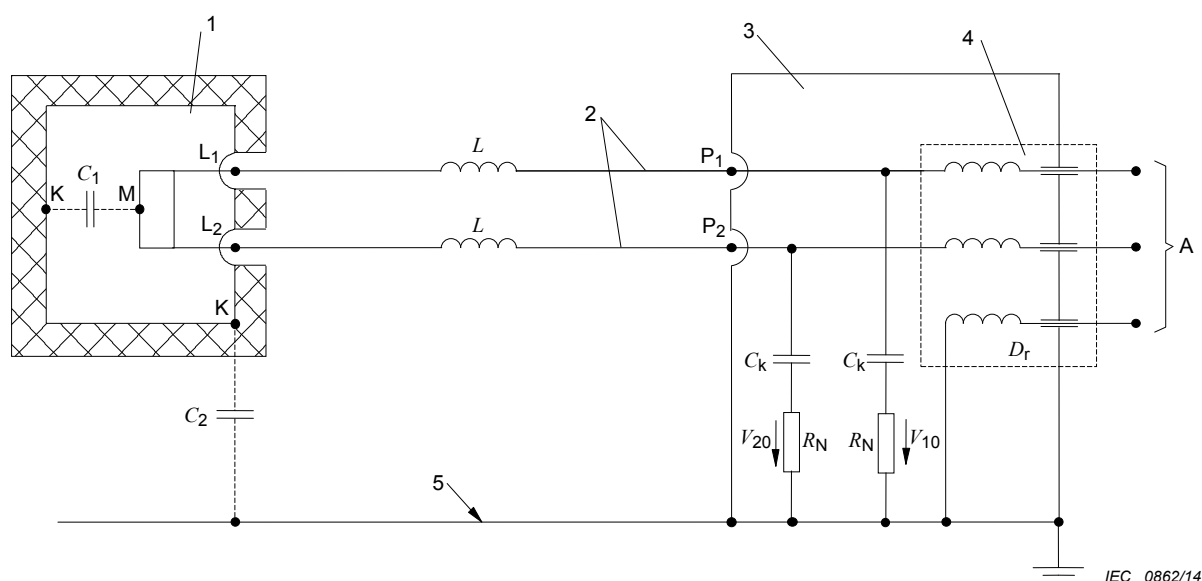
- 1 EUT
- 2 Power cord
- 3 AMN
- 4 Inductor and decoupling capacitor
- 5 Metallic wall
- A Power input
- B_0 Reference ground connection
- L_1, L_2 Power cord connection (100 cm)
- P_1, P_2 EUT plug to mains network
- C_1 Stray capacitance within EUT to metallic parts
- C_2 Stray capacitance of EUT to metallic wall (ground)
- C_K Coupling capacitors within mains network
- D_r Inductor (PE choke) for safety ground wire
- K Conductive structural parts of the EUT
- L Inductance of connecting wires
- M Fictitious mid-point of the internal voltages
- R_N Simulation resistances (50 Ω or 150 Ω)
- Z_s Symmetric internal impedance of EUT
- Z_{1u}, Z_{2u} Internal impedances of the EUT
- V_s Symmetric internal voltage of the EUT
- V_{1u}, V_{2u} Internal voltages of the EUT
- V_{10}, V_{20} External measurable unsymmetric voltage

Figure 15 – Equivalent circuit for measurement of unsymmetric disturbance voltage for safety-class I (grounded) EUT

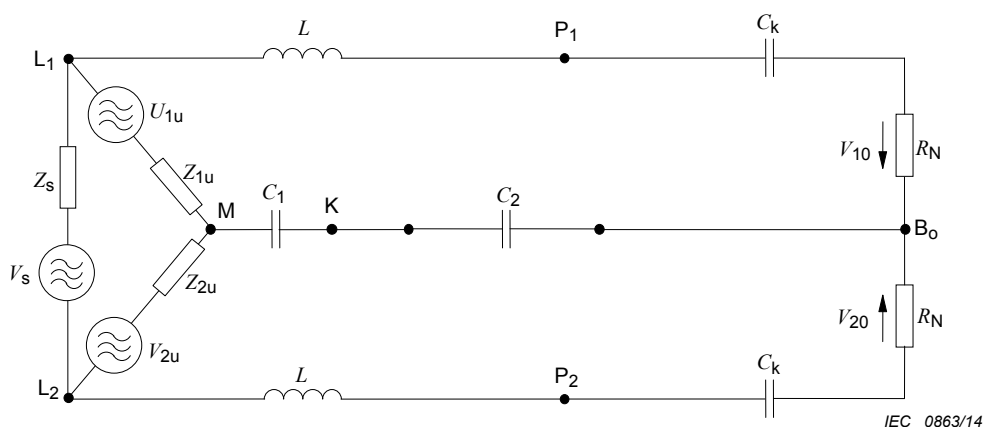
7.4.2.3 Arrangement of equipment without ground connection

Devices without ground connection comprise electrical devices with protective insulation (safety-class II) and devices which can be operated without ground or safety conductor (device of safety-class III) and also pluggable safety-class I devices connected via an isolating transformer. For these devices, the unsymmetric disturbance voltage of the individual conductors shall be measured with respect to the metal reference ground of the measurement arrangement as shown in the equivalent circuit of Figure 16.

Because in the long-wave 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 because the capacitance is determined by the specified distance, the arrangement shall be exactly followed and other external influences such as body and hand capacitance, for example, should be avoided.



a) Schematic for power and measurement circuit



b) Equivalent RFI source and measurement circuit

NOTE Refer to Figure 15 for explanation of symbols.

Figure 16 – Equivalent circuit for measurement of unsymmetric disturbance voltage for safety-class II (ungrounded) EUT

7.4.2.4 Arrangement of handheld equipment without a ground connection

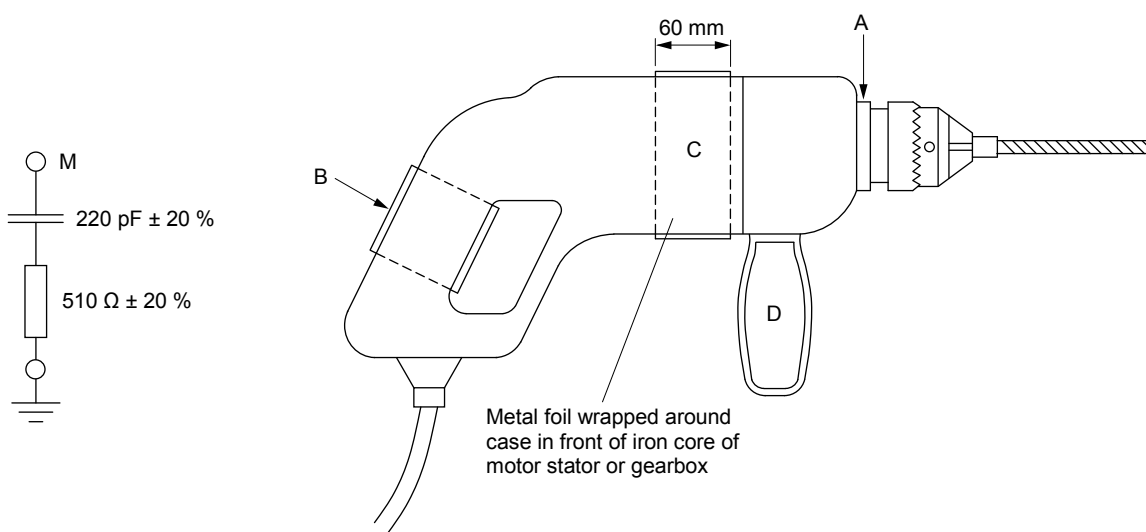
Measurements shall first be made in accordance with 7.4.2.3. Additional measurements shall then be made using the artificial hand (other details are described in CISPR 16-1-2).

The general principle to be followed in the application of the artificial hand is shown in Figure 18. 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 17) consisting of a capacitor of $220 \text{ pF} \pm 20 \%$ in series with a resistor of $510 \Omega \pm 10 \%$; the other terminal of the RC element shall be connected to the reference ground of the measuring system.

The artificial hand is to be applied in the following way:

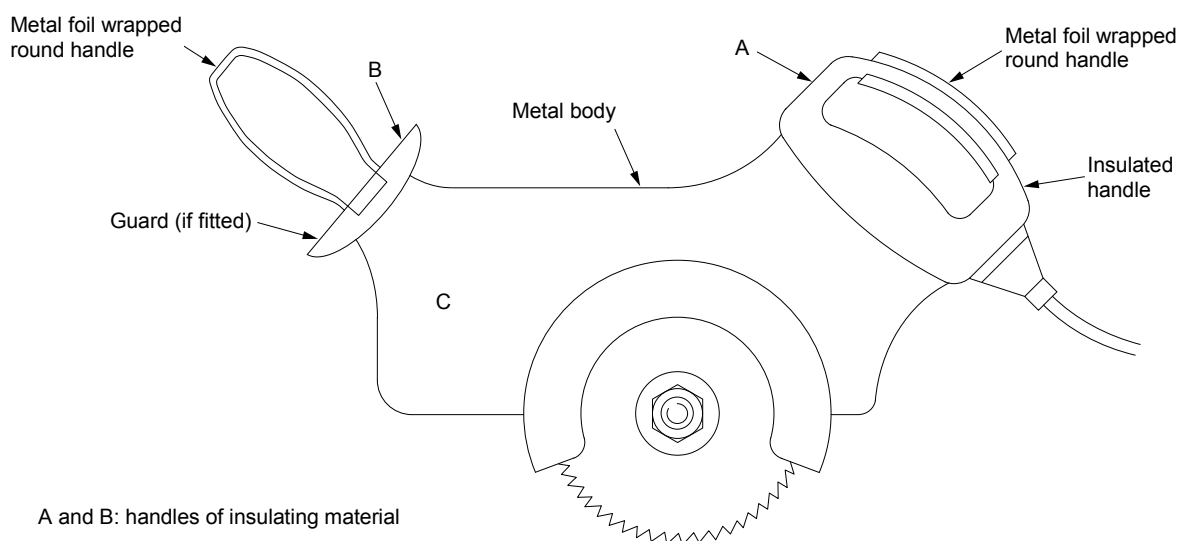
- a) when the case of the EUT is entirely of metal, no metal foil is needed, but the terminal M of the RC element shall be connected directly to the body of the EUT;
- b) when the case of the EUT is of insulating material, metal foil shall be wrapped around the handle B (Figure 18), and also around the 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 disturbance 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;
- 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 18). 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 disturbance 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 19), 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.



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Figure 17 – RC element for artificial hand

Figure 18 – Portable electric drill with artificial hand



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Figure 19 – Portable electric saw with artificial hand

7.4.2.5 Arrangement of keyboards, electrodes and other equipment sensitive to human touch

For keyboards, electrodes and other equipment sensitive to human touch, the artificial hand shall be applied as required by the product standards, and in general according to 7.4.2.4.

7.4.2.6 Arrangement 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 disturbance suppression device), or if shielded power cords are used, an additional 1 m long unshielded cable shall be connected between the suppression device and the AN for

measurement of the disturbance voltage. The line between the AN and the disturbance suppression device shall be placed in the direct proximity of the EUT.

7.4.2.7 Arrangement of equipment having auxiliary equipment (AuxEq) connected at the end of a lead other than the mains lead

Regulating controls incorporating semiconductor devices are excluded from 7.4.2.7; the provisions of 7.4.4.1 shall apply.

When the AuxEq is not essential to the operation of the EUT and has a separate test procedure specified elsewhere, 7.4.2.7 does not apply. The main EUT is tested as an individual EUT.

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 7.4.1.

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

The EUT shall be arranged in accordance with 7.4.2.1 through 7.4.2.6, with the following additional requirements:

- a) the AuxEq shall be placed at the same height as, and at the same distance from, the grounded conducting surface and if the lead is long enough it is to be treated in accordance with 7.4.1. If the auxiliary lead is shorter than 0,8 m, its length shall be maintained, and the AuxEq shall be placed as far away as possible from the main EUT. When the AuxEq is a control unit, the arrangements for its operation shall not affect the level of disturbance;
- b) if an EUT having an AuxEq 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 AuxEq;
- c) if the EUT is not made to be held in the hand, an AuxEq which is not grounded and is made to be held in the hand shall be connected to the artificial hand. If the AuxEq is not made to be held in the hand either, it shall be placed in relation to a grounded conducting surface as described in 7.4.1.

In addition to the measurement on the terminals for the mains connection, measurements are performed 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 AuxEq, control, or load is connected to allow measurements to be made under all provided operating conditions, and during interactions between the EUT and the AuxEq.

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

7.4.3 Measurement of common mode voltages at differential mode signal terminals

7.4.3.1 General

Generally, the measurement of disturbance voltages using ANs is the preferred CISPR measurement method. If e.g. an AN causes the EUT not to work, then measurements with current probes or capacitive voltage probes should be made.

7.4.3.2 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 CISPR 16-1-2, in the frequency range 150 kHz to 30 MHz. The delta-networks specified in CISPR 16-1-2 could be constructed so as 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 16-1-2 are complied with.

When using the delta-network for measurements on signal terminals, the differential mode rejection shall be as high as needed so as 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 AMN, all voltage measurements shall be carried out with both networks connected simultaneously. The provisions prescribed in 7.4.1 and 7.4.2 shall 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.

7.4.3.3 Measurements using the Y-type network

Alternatively an asymmetric (common mode) artificial network (AAN), i.e. a Y-type network according to CISPR 16-1-2, can be used for the measurement of common mode disturbance voltages in the frequency range 9 kHz to 30 MHz.

NOTE Y-type networks are frequently (e.g. in CISPR 22) called impedance stabilization networks (ISNs).

In contrast to the delta-network, which provides a differential mode and a common mode termination with equal simulation impedances of 150 Ω , the Y-network provides only a common mode termination of 150 Ω , and with the communication line terminated with its characteristic impedance and a differential to common mode rejection characteristic of the telecommunication network to which the EUT is intended to be connected.

At the supply side of the Y-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 to 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 Y-type network. If no suitable Y-network is available, the telecommunication port is terminated with AuxEq.

When an EUT with telecommunication port is to be measured on its power supply terminals using an AMN, the disturbance voltage measurements shall be carried out with AMN connected to the power port and Y-network connected to the telecommunication port simultaneously, or with the associated equipment directly connected to the EUT. Figure 9 shows the measurement arrangement with AMNs and Y-networks (ISNs). The provisions prescribed in 7.4.1 and 7.4.2 shall be observed.

7.4.4 Measurements using voltage probes

7.4.4.1 With an AMN

To test devices and systems with several connected or connectable lines, the disturbance voltage at the line connections that cannot be measured with AMN (e.g. for connecting lines between parts of components which are separated from the mains), as well as at the connecting jacks for antennas, control and load lines, shall be measured with a voltage probe