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BSI Standards Publication

Specification for radio disturbance and immunity measuring apparatus and methods

Part 2-3: Methods of measurement of disturbances and immunity — Radiated disturbance measurements

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National foreword

This British Standard is the UK implementation of EN 55016-2-3:2010+A2:2014. It is identical to CISPR 16-2-3:2010, incorporating amendments 1:2010 and 2:2014. It supersedes BS EN 55016-2-3:2010+A1:2010, which will be withdrawn on 18 April 2017.

BSI as a member of CENELEC, is obliged to publish the second amendment to EN 55016-2-3:2010+A2 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee voted against its approval as a European Standard. The concern in amendment 2 clause 7.3.6.3 is that it does not provide a representative simulation of mains cabling. The UK will continue to work to improve this standard and its application to dependent standards.

Technical justification was presented at the Tokyo EMC conference in May 2014 in the paper: *"Measurement Method, Uncertainty and Cable Balance - with Implications for the CDNE-M" by D M Lauder & R C Marshall, Paper 14A-A3, 2014 International Symposium on Electromagnetic Compatibility, May 12-16 2014, Tokyo, Japan*. This academic paper is available from the British Library.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CISPR text carry the number of the CISPR amendment. For example, text altered by CISPR amendment 1 is indicated by A1⟩ ⟨A1.

The UK participation in its preparation was entrusted by Technical Committee GEL/210, EMC – Policy committee, to Subcommittee GEL/210/12, EMC basic, generic and low frequency phenomena Standardization.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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ICS 33.100.10; 33.100.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2011.

Amendments/corrigenda issued since publication

Date	Text affected
30 June 2011	Implementation of CISPR Amendment 1:2010 with CENELEC endorsement A1:2010
30 September 2013	Supersession information removed from EN title page
30 September 2014	Implementation of CISPR amendment 2:2014 with CENELEC endorsement A2:2014

EUROPEAN STANDARD

NORME EUROPÉENNE

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EN 55016-2-3:2010+A2

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English version

Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements

(CISPR 16-2-3:2010)

Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques - Partie 2-3: Méthodes de mesure des perturbations et de l'immunité - Mesures des perturbations rayonnées
(CISPR 16-2-3:2010)

Anforderungen an Geräte und Einrichtungen sowie Festlegung der Verfahren zur Messung der hochfrequenten Störaussendung (Funkstörungen) und Störfestigkeit - Teil 2-3: Verfahren zur Messung der hochfrequenten Störaussendung (Funkstörungen) und Störfestigkeit - Messung der gestrahlten Störaussendung
(CISPR 16-2-3:2010)

This European Standard was approved by CENELEC on 2010-06-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Foreword

The text of document CISPR/A/886/FDIS, future edition 3 of CISPR 16-2-3, prepared by CISPR SC A, Radio-interference measurements and statistical methods, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 55016-2-3 on 2010-06-01.

This European Standard supersedes EN 55016-2-3:2006.

This EN 55016-2-3:2010 includes the following significant technical changes with respect to EN 55016-2-3:2006: addition of the measurand for radiated emissions measurements in an OATS and a SAC in the range of 30 MHz to 1 000 MHz, and addition of a new normative annex on the determination of suitability of spectrum analysers for compliance tests. Also, numerous maintenance items are addressed to make the standard current with respect to other parts of the EN 55016 series.

It has the status of a basic EMC publication in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-03-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-06-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard CISPR 16-2-3:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[1] CISPR 11:2009	NOTE	Harmonized as EN 55011:2009 (modified).
[3] CISPR 22:2008	NOTE	Harmonized as EN 55022:200X [1)] (modified).
[4] IEC 61140:2001	NOTE	Harmonized as EN 61140:2002 (not modified).
[6] ISO/IEC 17000:2004	NOTE	Harmonized as EN ISO/IEC 17000:2004 (not modified).
[7] IEC 61000-4-21	NOTE	Harmonized as EN 61000-4-21.

Foreword to amendment A1

The text of document CISPR/A/878/CDV, future amendment 1 to CISPR 16-2-3:2010, prepared by CISPR SC A, Radio-interference measurements and statistical methods, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 55016-2-3:2010 on 2010-10-01.

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– latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-07-01
– latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow)	2013-10-01

Endorsement notice

The text of amendment 1:2010 to the International Standard IEC 55016-2-3:2010 was approved by CENELEC as an amendment to the European Standard without any modification.

[1)] At draft stage.

Foreword to amendment A2

The text of document CISPR/A/1054/FDIS, future amendment 2 to edition 3 of CISPR 16-2-3, prepared by SC A "Radio-interference measurements and statistical methods" of IEC/TC CISPR "International special committee on radio interference" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 55016-2-3:2010/A2:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-01-18
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-04-18

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard CISPR 16-2-3:2010/A2:2014 was approved by CENELEC as a European Standard without any modification.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
CISPR 14-1	2005	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission	EN 55014-1	2006
CISPR 16-1-1	-	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus	EN 55016-1-1	-
CISPR 16-1-2	2003	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Conducted disturbances	EN 55016-1-2	2004
CISPR 16-1-4	2010	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements	EN 55016-1-4	2010
CISPR 16-2-1	2008	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements	EN 55016-2-1	2009
CISPR 16-4-1	-	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-1: Uncertainties, statistics and limit modelling - Uncertainties in standardized EMC tests	-	-
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	EN 55016-4-2	-
CISPR/TR 16-4-5	-	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-5: Uncertainties, statistics and limit modelling - Conditions for the use of alternative test methods	-	-

Publication	Year	Title	EN/HD	Year
IEC 60050-161	1990	International Electrotechnical Vocabulary (IEV) - Chapter 161: Electromagnetic compatibility	-	-
IEC 61000-4-3	2006	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test	EN 61000-4-3	2006
IEC 61000-4-20	-	Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides	EN 61000-4-20	-

CONTENTS

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements

1 Scope

This part of CISPR 16 specifies the methods of measurement of radiated disturbance phenomena in the frequency range of 9 kHz to 18 GHz. The aspects of measurement uncertainty are specified in CISPR 16-4-1 and CISPR 16-4-2.

NOTE In accordance with IEC Guide 107, CISPR 16-2-3 is a basic EMC publication 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

CISPR 16-1-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances*
Amendment 1 (2004)
Amendment 2 (2006)

CISPR 16-1-4:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*

CISPR 16-2-1:2008, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR 16-4-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests*

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*

CISPR 16-4-5, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-5: Uncertainties, statistics and limit modelling – Conditions for the use of alternative test methods*

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

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1 (2007)

IEC 61000-4-20, *Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides*

3 [A2⟩Terms, definitions and abbreviations ⟨A2]

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

3.1
absorber-lined OATS/SAC
OATS or SAC with ground plane partially covered by RF-energy absorbing material

3.2
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

3.3
antenna beam
main lobe of the antenna pattern (gain pattern) of the receive antenna (usually the direction with maximum sensitivity or lowest antenna factor) that is directed towards the EUT

3.4
antenna beamwidth
angle between the half-power (3 dB) points of the main lobe of the antenna beam, when referenced to the maximum power of the main lobe. It may be expressed for the H plane or for the E plane of the antenna

NOTE Antenna beamwidth is expressed in degrees.

3.5
associated equipment
AE
apparatus, that is not part of the system under test, but needed to help exercise the EUT

3.6
auxiliary equipment
AuxEq
peripheral equipment that is part of the system under test

3.7
basic standard
standard that has a wide-ranging coverage or contains general provisions for one particular field

NOTE A basic standard may function as a standard for direct application or as a basis for other standards.

[ISO/IEC Guide 2, definition 5.1]

3.8
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

3.9
common-mode absorption device
CMAD
device that may be applied on cables leaving the test volume in radiated emission measurements to reduce the compliance uncertainty

[CISPR 16-1-4, 3.1.4]

3.10
conformity assessment
demonstration that specified requirements relating to a product, process, system, person or body are fulfilled

NOTE The subject field of conformity assessment includes activities defined elsewhere in ISO/IEC 17000:2004, such as testing, inspection and certification, as well as the accreditation of conformity assessment bodies.

[ISO/IEC 17000:2004, 2.1, modified]

3.11
continuous disturbance
RF disturbance with duration of more than 200 ms at the IF-output of a measuring receiver that causes a deflection on the meter of a measuring receiver in quasi-peak detection mode, and that does not decrease immediately

[IEC 60050-161:1990, 161-02-11, modified]

3.12
(electromagnetic) emission
phenomenon by that electromagnetic energy emanates from a source

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

3.13
emission limit (from a disturbing source)
specified maximum emission level of a source of electromagnetic disturbance

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

3.14
equipment-under-test
EUT
equipment (devices, appliances and systems) subjected to EMC (emission) compliance (conformity assessment) tests

3.15
fully-anechoic room
FAR
shielded enclosure, the internal surfaces of which are lined with radio-frequency-energy absorbing material (i.e. RF absorber) that absorbs electromagnetic energy in the frequency range of interest

3.16
loop-antenna system
LAS
antenna system consisting of three orthogonally-oriented loop antennas that are used to measure the three orthogonal magnetic dipole moments of an EUT located in the centre of the three loops

3.17
measurement, scan and sweep times

3.17.1
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 rms detector, the effective time to determine the rms of the signal envelope

3.17.2
scan
continuous or stepped frequency variation over a given frequency span

3.17.3
span
Δf
difference between stop and start frequencies of a sweep or scan

3.17.4
sweep
continuous frequency variation over a given frequency span

3.17.5
sweep or scan rate
frequency span divided by the sweep or scan time

3.17.6
sweep or scan time
T_s
time between start and stop frequencies of a sweep or scan

3.17.7
observation time
T_o
sum of measurement times T_m on a certain frequency in case of multiple sweeps; if n is the number of sweeps or scans, then $T_o = n \times T_m$

3.17.8
total observation time
T_{tot}
effective time for an overview of the spectrum (either single or multiple sweeps); if c is the number of channels within a scan or sweep, then $T_{tot} = c \times n \times T_m$

3.18
measuring receiver
[A1] instrument such as a tunable voltmeter, an EMI receiver, a spectrum analyzer or an FFT-based measuring instrument, with or without preselection, that complies with CISPR 16-1-1 [/A1]

3.19
number of sweeps per time unit (e.g. per second)
n_s
reciprocal of the sum of sweep time and retrace time, i.e. 1 / (sweep time + retrace time)

3.20
open-area test site
OATS
facility used for measurements of electromagnetic fields the intention for which is to simulate a semi-free-space environment over a specified frequency range that is used for radiated emission testing of products. An OATS typically is located outdoors in an open area, and has an electrically-conducting ground plane.

3.21
product standard
standard that specifies requirements to be fulfilled by a product or group of products, to establish its fitness for purpose

NOTE 1 A product standard may include, in addition to the fitness-for-purpose requirements, directly or by reference, aspects such as terminology, sampling, testing, packaging and labelling and, sometimes, processing requirements.

NOTE 2 A product standard can either be complete or not, according to whether it specifies all or only a part of the necessary requirements. In this respect, one may differentiate between standards such as dimensional, material and technical delivery standards.

[ISO/IEC Guide 2, definition 5.4]

3.22
semi-anechoic chamber
SAC
shielded enclosure in which five of the six internal surfaces are lined with radio-frequency-energy absorbing material (i.e. RF absorber) that absorbs electromagnetic energy in the frequency range of interest, and the bottom horizontal surface is a conducting ground plane for use with OATS test set

3.23
test configuration
combination that gives the specified measurement arrangement of the EUT in which an emission level is measured

3.24
weighting (of e.g. impulsive disturbance)
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 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 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 that perfect error correction can still occur or by another, objective and reproducible parameter

3.24.1
weighted disturbance measurement
measurement of disturbance using a weighting detector

3.24.2
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

3.24.3
weighting detector
detector that provides an agreed weighting function

3.24.4
weighting factor
value of the weighting function relative to a reference PRF or relative to the peak value

NOTE Weighting factor is expressed in dB.

3.24.5
weighting function or 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

A1) **3.25**
measurement
process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

[2.1 of ISO/IEC Guide 99:2007][8][1]

3.26
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 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.

[IEC 60050-151:2001, 151-16-13][9] (A1

A2) **3.27**
highest internal frequency
highest frequency generated or used within the EUT or the highest frequency at which the EUT operates or tunes

3.28
module
part of an EUT that provides a function and may contain radio-frequency sources

3.29 Abbreviations[2]

The following abbreviations, not already provided in 3.1 through 3.28, are used in this standard.

AM	Amplitude modulation
APD	Amplitude probability distribution
AV	Average
BB	Broadband
CW	Continuous wave
FFT	Fast-Fourier transform
FM	Frequency modulation
IF	Intermediate frequency
ISM	Industrial, scientific or medical (A2

A1) 1 Figures in square brackets refer to the Bibliography. (A1

A2) 2 At the next maintenance, when a new edition is published, terms and definitions will be placed in a new subclause 3.1 and renumbered, and abbreviations will be re-located to a new subclause 3.2. (A2

A2 LPDA	Log-periodic dipole array
NB	Narrowband
NSA	Normalized site attenuation
PRF	Pulse repetition frequency
RBW	Resolution bandwidth
RF	Radio frequency
RGP	Reference ground plane
QP	Quasi-peak
TEM	Transverse electromagnetic
UFA	Uniform field area
VBW	Video bandwidth A2

4 Types of disturbance to be measured

4.1 General

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

4.2 Types of disturbance

For physical and psychophysical[1] reasons, dependent on the spectral distribution, measuring receiver bandwidth, the duration, rate of occurrence, and degree of annoyance during the assessment and measurement of radio disturbance, distinction is made between the following types of disturbance:

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

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

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

The frequency spectra of items 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 that is wider than the bandwidth of the measuring receiver specified in CISPR 16-1-1.

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1 Psychophysical means psychological relationship between physical stimuli and sensory response.

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 rms-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 that 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

Concerning the connection of measuring equipment, measuring receivers and ancillary equipment such as antennas: 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 output of the ancillary equipment shall be terminated with the prescribed impedance.

6 General measurement requirements and conditions

6.1 General

Radio disturbance measurements shall be:

- reproducible, i.e. independent of the measurement location and environmental conditions, especially ambient noise; and
- free from interactions, i.e. the connection of the EUT to the measuring equipment shall influence neither 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;

[A1) *Text deleted* (A1]

6.2 Disturbance not produced by the equipment under test

6.2.1 General

[A1) 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. (A1]

6.2.2 Compliance (conformity assessment) testing

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

[A2⟩ When evaluating compliance with a limit, ⟨A2] the ambient noise level is permitted to exceed the preferred -6 dB level provided that the level of both ambient noise and source emanation combined does not exceed the specified limit. The EUT is then considered to meet the limit. [A2⟩ Further guidance on measurement of disturbances in the presence of ambient emissions is provided in Annex A. ⟨A2]

[A2⟩ *Text deleted* ⟨A2]

6.3 Measurement of continuous disturbance

6.3.1 Narrowband continuous disturbance

The receiver shall be kept tuned to the discrete frequency under investigation, and re-tuned if the frequency fluctuates.

6.3.2 Broadband continuous disturbance

For the assessment of broadband continuous disturbance the level of which is not steady, the maximum reproducible measurement value shall be found. See 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 must be given to certain characteristics of these instruments, which include overload, linearity, selectivity, normal response to pulses, frequency scan rate, signal interception, sensitivity, amplitude accuracy and peak, average and quasi-peak detection. These characteristics are considered in Annex B.

6.4 [A2⟩ EUT arrangement and measurement conditions ⟨A2]

The EUT shall be operated under the following conditions:

[A2⟩ 6.4.1 General arrangement of the EUT

6.4.1.1 General

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

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, that practice shall be used in the test arrangement, where possible. This arrangement shall be typical of 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 have to be added to the EUT depending upon the results of preliminary tests. Connecting a cable or wire to just one of that type of port may be sufficient. The actual number of additional cables or wires may be limited to the condition where the addition of another cable or wire does not significantly affect the emission level, i.e. varies 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. ⟨A2]

A2 If shielded or special cables are used during the tests to achieve compliance, then 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.

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. This is permissible because it has been found that disturbances from identical modules are generally not additive in practice. However the 2 dB criteria defined in this clause shall be applied.

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 (drawer, plug-in card, board, etc.) 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 may be limited to the condition where the addition of another board or plug-in card does not significantly affect the emission level, i.e. varies less than 2 dB, provided that the EUT remains compliant. The rationale used for selecting the number and type of modules shall 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 be representative of that used in a typical installation. The rationale used for selecting units shall be stated in the test report.

At least one module of each type shall be operative in each equipment evaluated in an EUT. For a system EUT, at least one of each type of equipment that can be included in the possible system configuration shall be included in the EUT.

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, a RGP, and tabletop equipment is placed on a non-conductive table.

Equipment designed for wall-mounted or ceiling 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 shall be terminated using the correct terminating impedance defined in the product standard.

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

Auxiliary equipment shall be installed in accordance with normal installation practice. Where this means that the auxiliary equipment is located on the test site, it shall be arranged using the same conditions applicable for the EUT (e.g distance from ground plane and insulation from the ground plane if floor standing, and layout of cabling). A2

A2) 6.4.1.2 Tabletop arrangement

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.

All units forming the system under test (including the EUT, connected peripherals and auxiliary equipment or devices) shall be arranged according to normal use. Where not defined in the normal use, a nominal 0,1 m separation distance between the neighbouring units shall be defined for the test arrangement.

Intra-unit cables shall be draped over the back of the table. If a cable hangs closer than 0,4 m to 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 bundle is at least 0,4 m above the horizontal RGP.

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 unit 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 Floor-standing arrangement

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 ground plane.

Intra-unit cables (between units forming the EUT or between the EUT and auxiliary equipment) shall drape to, but remain insulated from, the horizontal RGP. Any excess 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 Combinations of tabletop and floor-standing equipment arrangement

Intra-unit cables between a tabletop unit and a floor standing unit shall have the excess 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. (A2

A2 6.4.2 Operation of the EUT

The operating conditions of the EUT shall be determined by the manufacturer according to the typical use of the EUT with respect to the expected highest level of emission. The determined operational mode and the rationale for the selected operating conditions shall be stated in the test report.

The EUT shall be operated within the rated (nominal) operating voltage range and typical load conditions (mechanical or electrical) for which it is designed. Actual loads should be used whenever possible. If a simulator is used, it shall represent the actual load with respect to its radio frequency and functional characteristics.

The test programmes or other means of exercising the equipment should ensure that various parts of a system are exercised in a manner that permits detection of all system disturbances.

6.4.3 EUT time of operation

The time of operation shall be, in the case of EUTs with a given rated operating time, in accordance with the marking; in all other cases, the EUT shall be continuously operated throughout the test.

6.4.4 EUT running-in time

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

6.4.5 EUT supply

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

6.4.6 EUT mode of operation

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

6.4.7 Operation of multifunction equipment

Multifunction equipment which 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 and/or standards when each function has satisfied the requirements of the relevant clause and/or standard.

For equipment where 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 and/or standard with the necessary functions operated. A2

A2 6.4.8 Determination of arrangement(s) causing maximum emissions

Initial testing shall identify the frequency that has the highest disturbance relative to the limit. This identification shall be performed while 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 has been identified.

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

6.4.9 Recording of measurements

Of those disturbances above (L – 20 dB), where L is the limit level in logarithmic units, the disturbance levels and the frequencies of at least the six highest disturbances shall be recorded.

For radiated disturbances, the antenna polarization and height for each reported disturbance shall be recorded. A2

6.5 Interpretation of measuring results

6.5.1 Continuous disturbance

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

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

   1) if the EUT is one that 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 that 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

There is currently no requirement for the measurement of radiated discontinuous disturbances.

A1) 6.5.3 Measurement of the duration of disturbance

The duration of a disturbance must 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. (A1

6.6 Measurement times and scan rates for continuous disturbance

6.6.1 General

For both manual measurements and automated or semi-automated measurements, measurement times and scan rates of measuring and scanning receivers shall be set so as to measure the maximum emission. Especially, where a peak detector is used for pre-scans, the measurement times and scan rates have to take the timing of the emission under test into account. More detailed guidance about performing automated measurements can be found in Clause 8.

6.6.2 Minimum measurement times

A2) The minimum measurement (dwell) times are given in Table 7. From Table 7, the minimum scan times for measurements over a complete CISPR band have been derived in Table 1. These minimum measurement (dwell) times for scanning receivers and FFT-based measuring instruments in Table 7 and the scan times for spectrum analyzers in Table 1 apply to CW signals.

In addition, the test report shall include the value of the measurement instrumentation uncertainty corresponding to the used test setup, calculated as per the requirements of CISPR 16-4-2. (A2

[A1› Table 7 – 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

‹A1]

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

[A2› *Text deleted* ‹A2] Depending on the type of disturbance, the scan time may have to be increased – even for quasi-peak measurements. In extreme cases, the measurement time T_m at a certain frequency may have to be increased to 15 s, if the level of the observed emission is not steady (see 6.5.1). However isolated clicks are excluded.

Scan rates and measurement times for use with the average detector are given in Annex C.

Most product standards call out quasi-peak detection for compliance measurements, which can be very time-consuming if time-saving procedures are not applied (see Clause 8). Before timesaving procedures can be applied, the emission has to be detected using a pre-scan. To ensure that, e.g. intermittent signals are not missed during an automated scan, the considerations in 6.6.3 to 6.6.5 shall be accounted for.

6.6.3 Scan rates for scanning receivers and spectrum analyzers

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

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

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

$$T_{\mathrm{s\,min}} = k \times \frac{\Delta f}{B_{\mathrm{res}}^2} \tag{1}$$

where

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

Δf is the frequency span,

B_{res} is resolution bandwidth, and

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

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

$$T_{\mathrm{s\,min}} = k \times \frac{\Delta f}{B_{\mathrm{res}}\,B_{\mathrm{video}}} \tag{2}$$

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 overridden if longer observation times are required, e.g. to intercept slowly varying signals.

In addition, for repetitive sweeps, the number of sweeps per second will be determined by the sweep time $T_{\mathrm{s\,min}}$ 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 % of the resolution bandwidth used or less (depending on the resolution filter shape) is required to reduce measurement uncertainty for narrowband signals due to the step-width. Under these assumptions the scan time $T_{\mathrm{s\,min}}$ for a stepping receiver can be calculated using the following equation:

$$T_{\mathrm{s\,min}} = T_{\mathrm{m\,min}} \times \frac{\Delta f}{0{,}5\,B_{\mathrm{res}}} \tag{3}$$

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

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

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

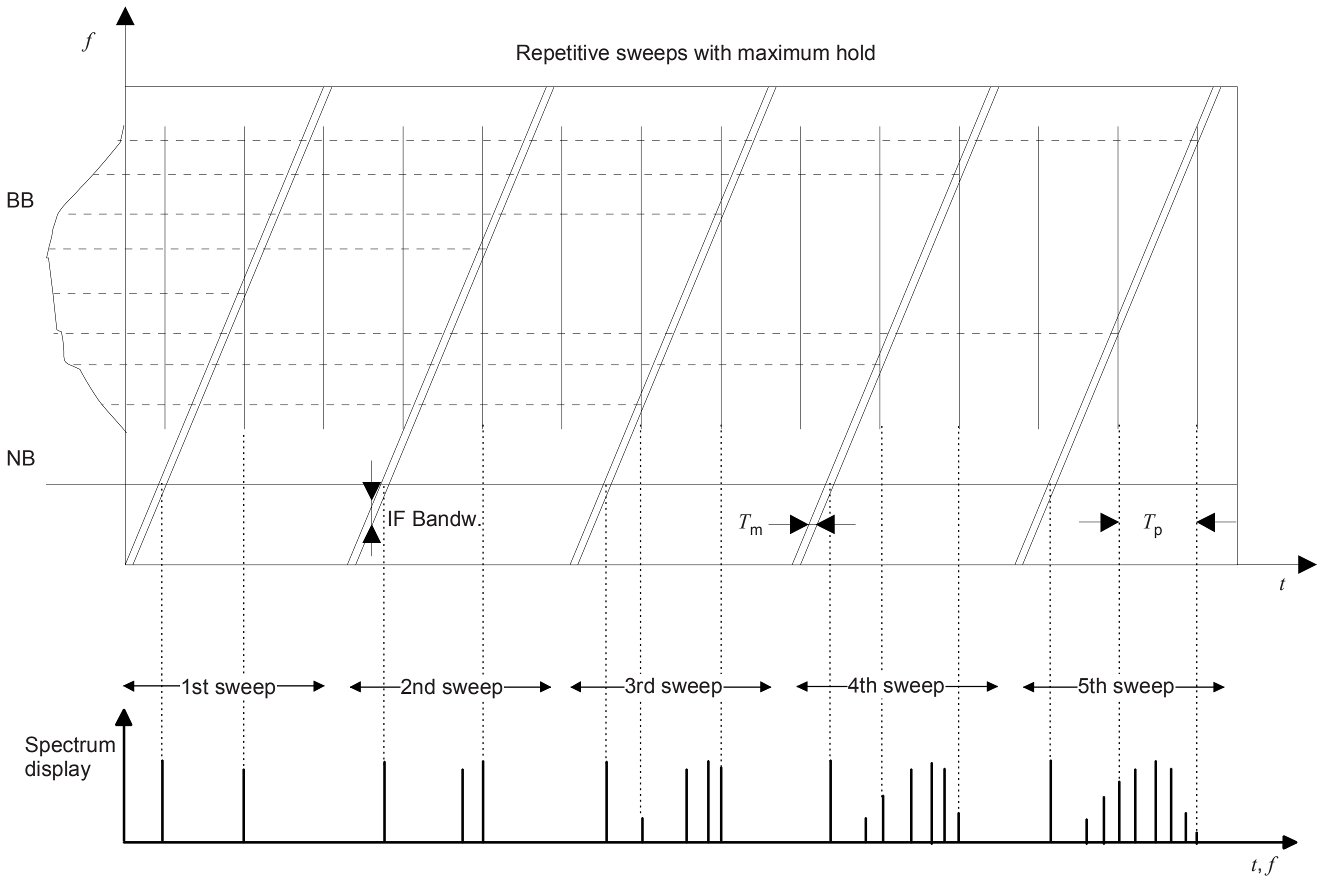
6.6.5 Strategies for obtaining a spectrum overview using the peak detector

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

– stepped scan: the measurement (dwell) time shall be long enough at each frequency to measure the signal peak, e.g. for an impulsive signal the measurement (dwell) time should be longer than the reciprocal of the repetition frequency of the signal.

– swept scan: the measurement time must be larger than the intervals between intermittent signals (single sweep) and the number of frequency scans during the observation time should be maximized to increase the probability of signal interception.

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



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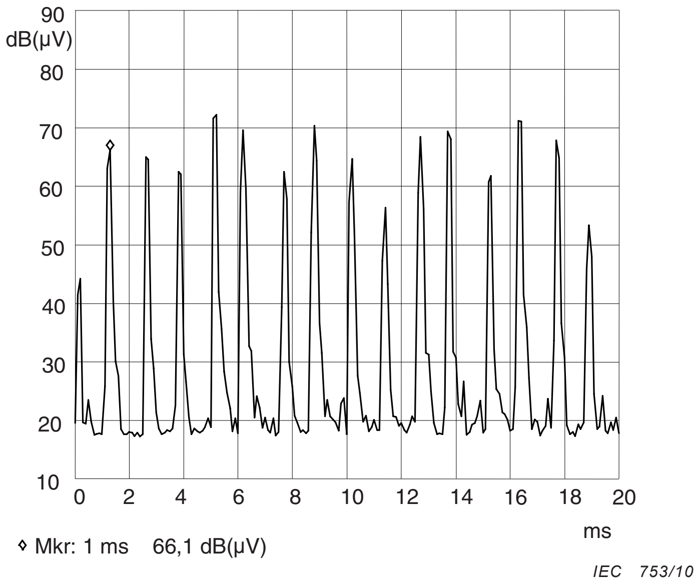
T_o is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum-vs.-time display (upper part of the figure).

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

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

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



NOTE Disturbance from a d.c. collector motor; due to the number of collector segments, the pulse repetition frequency is high (approximately 800 Hz) and the pulse amplitude varies considerably. Therefore for this example, the recommended measurement (dwell) time with the peak detector is > 10 ms.

Figure 2 – Example of a timing analysis

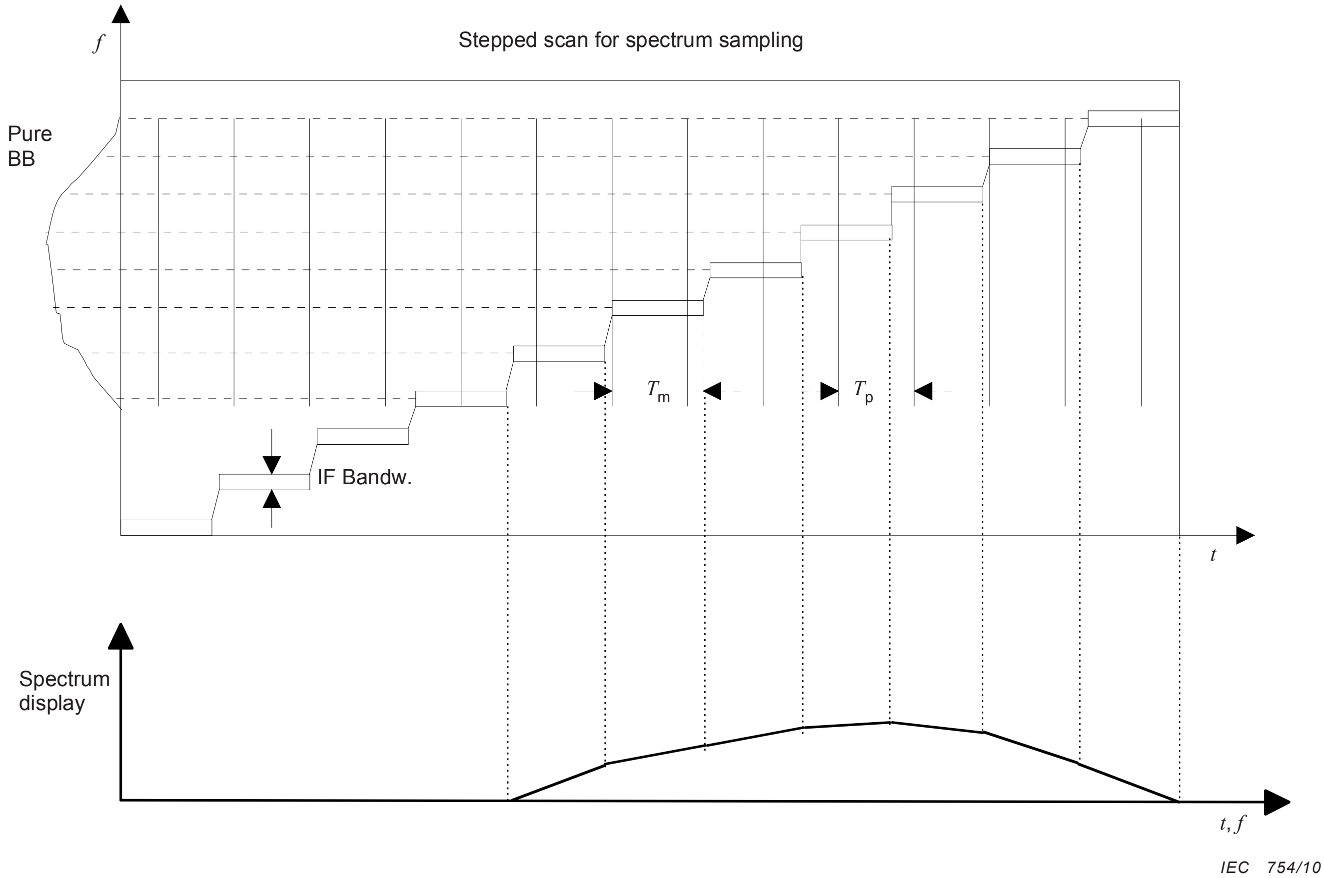
From such a timing analysis, pulse durations and pulse repetition frequencies can be determined and scan rates or dwell times selected, and according to the following:

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

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

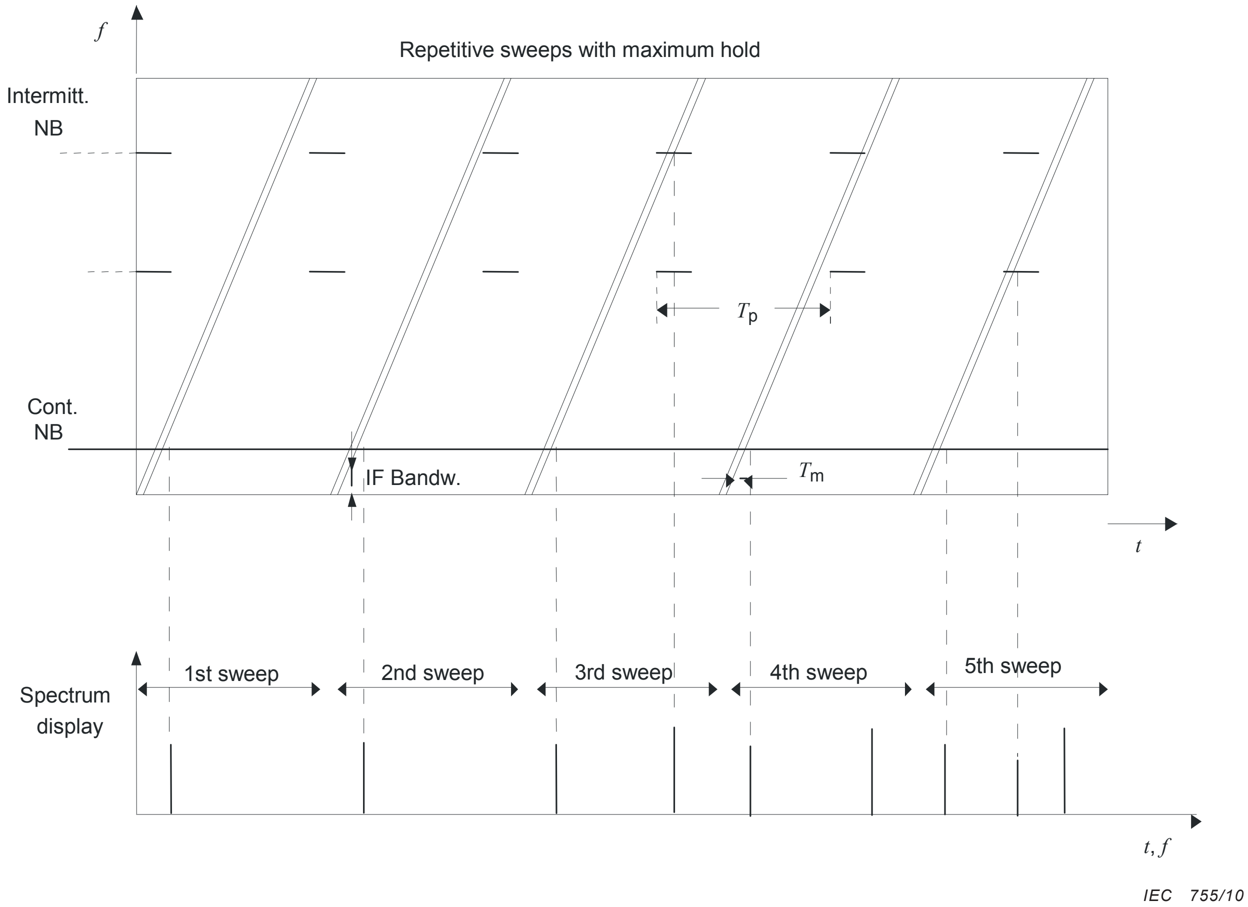
– for **intermittent narrowband** disturbances with unknown frequencies either fast short sweeps involving a “maximum hold” function (see Figure 4) or a slow single sweep may be used. A timing analysis may be required prior to the actual measurement to ensure proper signal interception.

– **intermittent broadband** disturbances shall be measured with discontinuous disturbance analysis procedures, as described in CISPR 16-1-1.



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

Figure 3 – A broadband spectrum measured with a stepped receiver



NOTE 1 The number of sweeps required or the sweep time may have to be increased, depending on pulse duration and pulse repetition interval.

NOTE 2 In this example, five sweeps are required for all spectral components to be intercepted.

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

A1) 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 20 for three segments. The total scan time for the frequency range of interest T_{scan} is calculated as:

$$T_{scan} = T_m N_{seg} \tag{18}$$

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 $f_{step\ FFT}$ 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 frequency step, $f_{step\ final}$. (A1

A1 Hence the first calculation over the given frequency range considers the following frequencies:

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

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

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

This procedure, applied for a step ratio of 3, is displayed on Figure 21.

The scan time T_{scan} is calculated as:

$$T_{\text{scan}} = T_{\text{m}} \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \tag{19}$$

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:

$$T_{\text{scan}} = T_{\text{m}} N_{\text{seg}} \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \tag{20}$$

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

A2 NOTE 2 Additional background information on the definition of the FFT-based receiver can be found in CISPR 16-3 [2]. A2

A2 *Text deleted* A2

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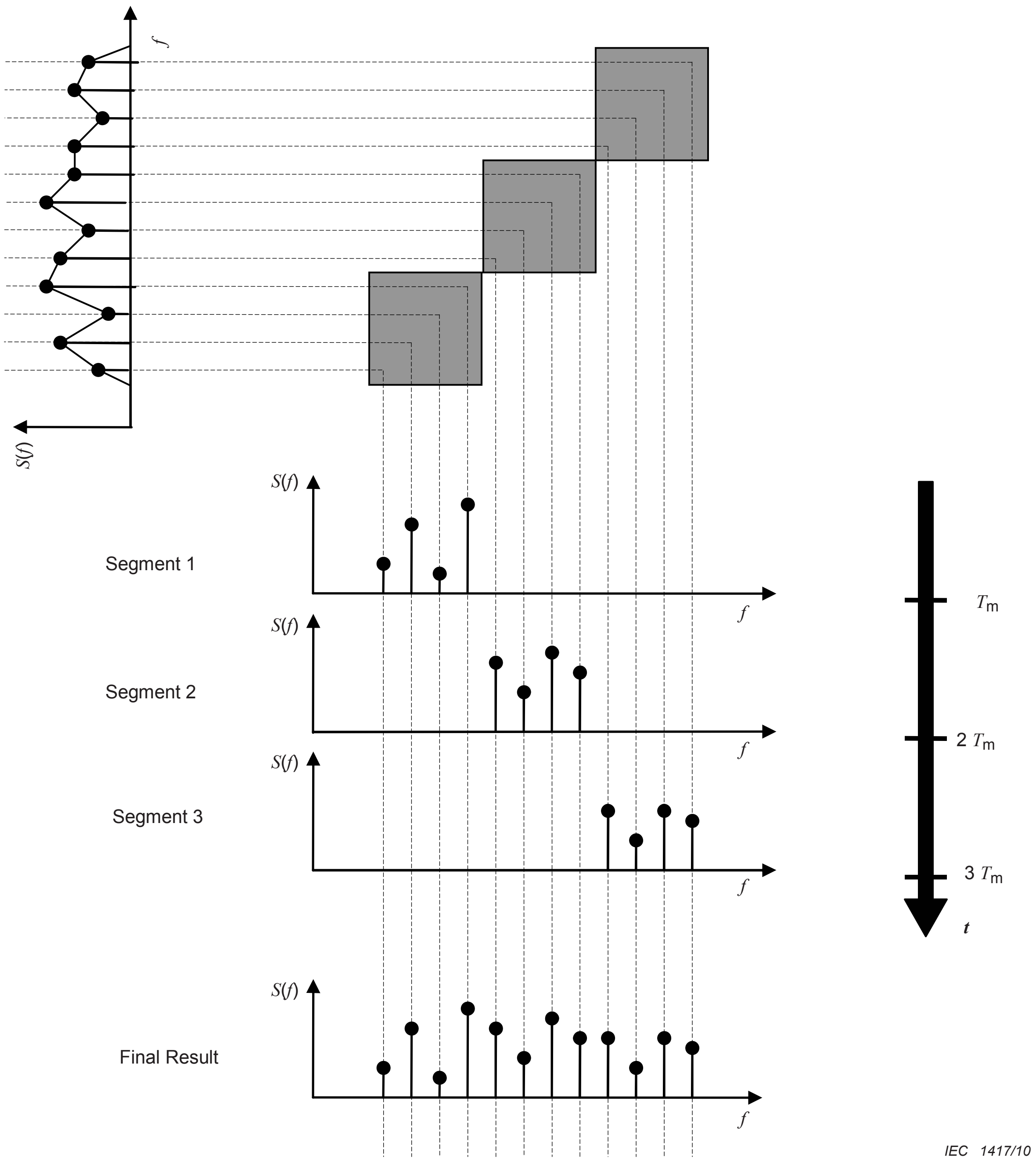

Figure 20 – FFT scan in segments

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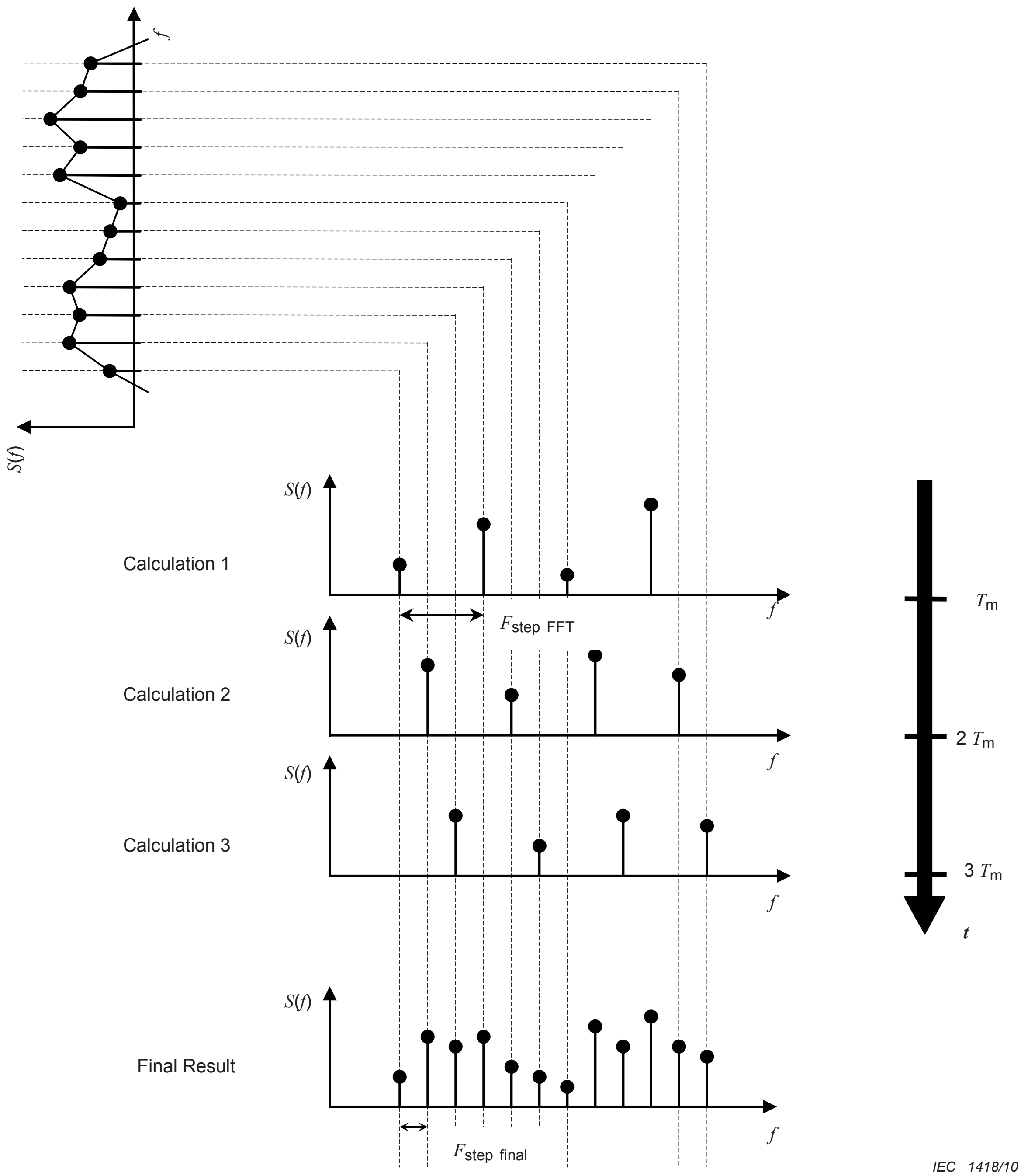

Figure 21 – Frequency resolution enhanced by FFT-based measuring instrument

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7 Measurement of radiated disturbances

7.1 Introductory remarks

This clause sets forth the general procedures for the measurement of the field strength of radio disturbance produced by devices and systems. Experience with radiated disturbance measurements is less extensive than that of voltage measurements. The radiated disturbance measurement procedures are therefore open to revision and extension as knowledge and experience are accumulated. In particular, attention shall be given to the effect of leads and cables associated with the EUT. Table 2 provides a summary list of CISPR radiated emission test sites and test methods and the related cross-references to subclauses within this document or to other documents.

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

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

Table 2 – Applicable frequency ranges and document references for CISPR radiated emission test sites and test methods

Site / method	9 kHz to 30 MHz	30 MHz to 1 000 MHz	1 GHz to 18 GHz
Outdoor site	tbd	7.3.8	n/a
LAS	7.2	n/a	n/a
OATS or SAC	tbd	7.3	n/a
FAR	n/a	7.4	7.6
Common RE/RI	n/a	7.5 (RI start 80 MHz)	n/a
Absorber-lined OATS	n/a	n/a	7.6
In-situ	7.7.2	7.7.3, 7.7.4.2	7.7.3, 7.7.4.3
Substitution	n/a	7.8	7.8
Reverberation chamber	n/a	7.9 (Start 80 MHz)	7.9
TEM waveguide	IEC 61000-4-20	7.10	7.10
n/a = not applicable; tbd = to be determined or is under consideration			

7.2 Loop-antenna system measurements (9 kHz to 30 MHz)

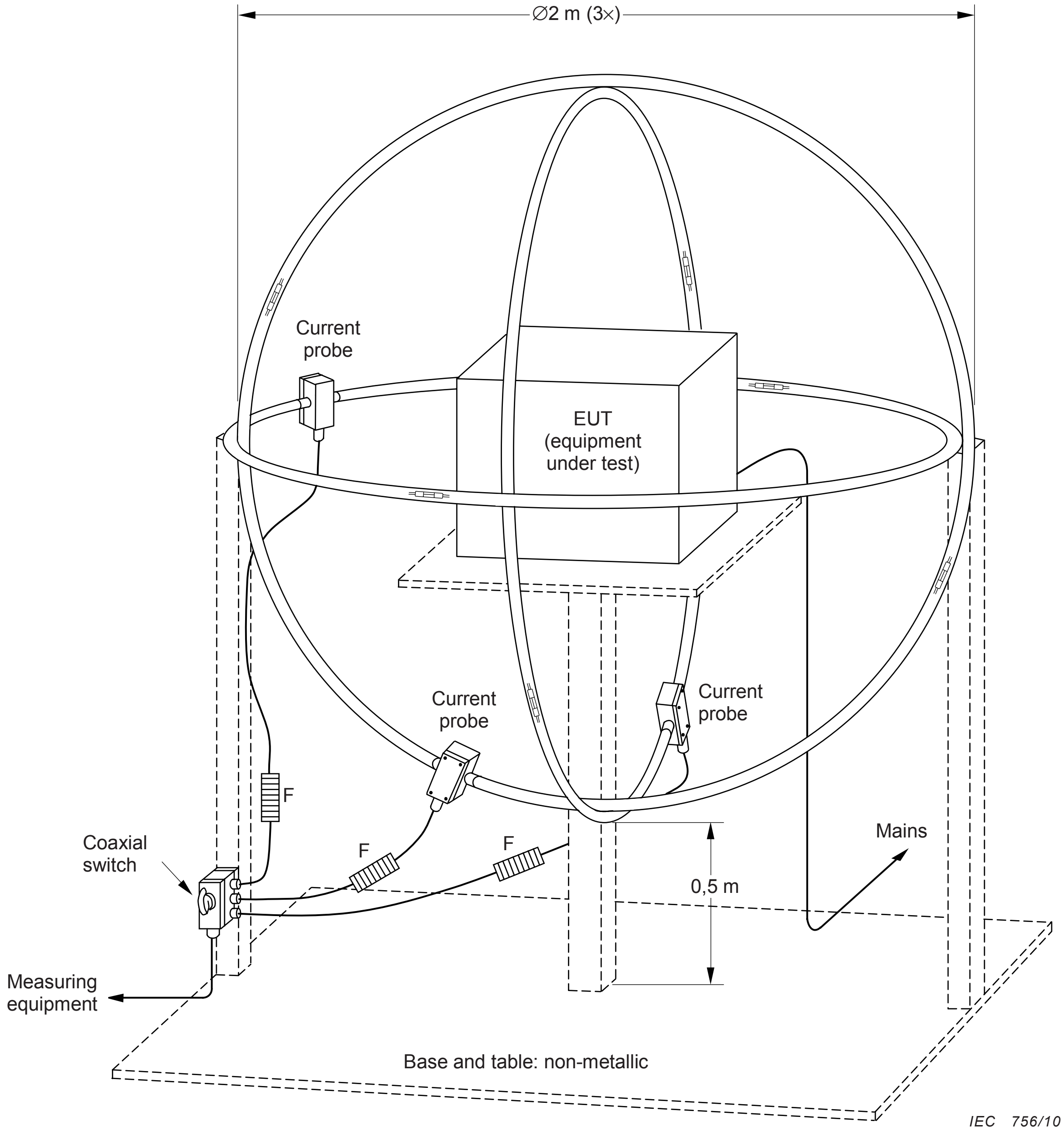
7.2.1 General

The loop antenna system (LAS) considered in this subclause is suitable for indoor measurement of the magnetic field strength emitted by a single EUT in the frequency range 9 kHz to 30 MHz. The magnetic field strength is measured in terms of the currents induced into the LAS by the magnetic disturbance field of the EUT. The LAS shall be validated regularly using the method described in CISPR 16-1-4. CISPR 16-1-4 also gives a complete description of the LAS and a relation between the measuring results obtained with the LAS and those obtained as described in this subclause.

7.2.2 General measurement method

Figure 5 shows the general concept of measurements made with the LAS. The EUT is placed in the centre of the LAS. The current induced by the magnetic field from the EUT into each of the three large loop antennas of the LAS is measured by connecting the current probe of the large loop antenna to a measuring receiver (or equivalent). During the measurements, the EUT remains in a fixed position.

The currents in the three large loop antennas, originating from the three mutually orthogonal magnetic field components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dB(µA), as specified in the product standard. The emission limit shall apply for an LAS having large loop antennas with the standardized diameter of 2 m.



F: ferrite absorber

Figure 5 – Concept of magnetic field induced current measurements made with the loop antenna system

7.2.3 Test environment

The distance between the outer perimeter of the LAS and nearby objects, such as floor and walls, shall be at least 0,5 m. The currents induced in the LAS by an RF ambient field shall be judged in accordance with CISPR 16-1-4.

7.2.4 Configuration of the equipment under test

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

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

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

a) the current values measured shall be corrected in accordance with B.6 of CISPR 16-1-2; and
b) the maximum dimensions of the EUT shall allow a distance between the EUT and the large loops of at least $(0,1 \times D)$ m, where D is the diameter of the non-standardized loop.

7.2.5 Measurement uncertainty for LAS

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.3 Open-area test site or semi-anechoic chamber measurements (30 MHz to 1 GHz)

7.3.1 Measurand

The quantity to be measured is the maximum electric field strength emitted by the EUT as a function of horizontal and vertical polarization and at heights between 1 m and 4 m, and at a horizontal distance of 10 m from the EUT, over all angles in the azimuth plane. This quantity shall be determined with the following provisions:

a) the frequency range of interest is 30 MHz to 1 000 MHz;
b) the quantity shall be expressed in terms of field strength units that correspond with the units used to express the limit levels for this quantity;
c) a SAC/OATS measurement site and positioning table shall be used that complies with the applicable CISPR validation requirements;
d) a measuring receiver compliant with CISPR 16-1-1 shall be used;
e) the use of alternative measurement distances, such as 3 m or 30 m instead of 10 m, shall be considered as alternative measurement methods;
f) the measurement distance is the horizontal projection of the distance between the boundary of the EUT and the antenna reference point to the ground plane;
g) the EUT is configured and operated in accordance with the CISPR specifications;
h) free-space antenna factors shall be used.

The measurand E is derived from the maximum voltage reading V_r by using the free-space antenna factor F_a:

$$E = V_r + A_c + F_a \qquad (4)$$

where

E is the field strength in dB(μV/m) as in the measurand description;

V_r is the maximum received voltage in dB(μV) using the procedure as in the measurand description;

A_c is the loss in dB of the measuring cable between antenna and receiver;

F_a is the free-space antenna factor of the receive antenna in dB(m^{-1}).

NOTE Free-space antenna factors are used as a figure of merit for the antenna. It should be noted the field strength is measured above a ground plane, not in a free-space environment.

7.3.2 Test site requirements

The test site shall conform to the relevant specifications of CISPR 16-1-4 for its physical and electrical properties, and for its validation.

7.3.3 General measurement method

Figure 6 shows the concept of measurements made on an open-area test site (OATS) or in a semi-anechoic chamber (SAC) with the direct and ground reflected rays arriving at the receiving antenna.

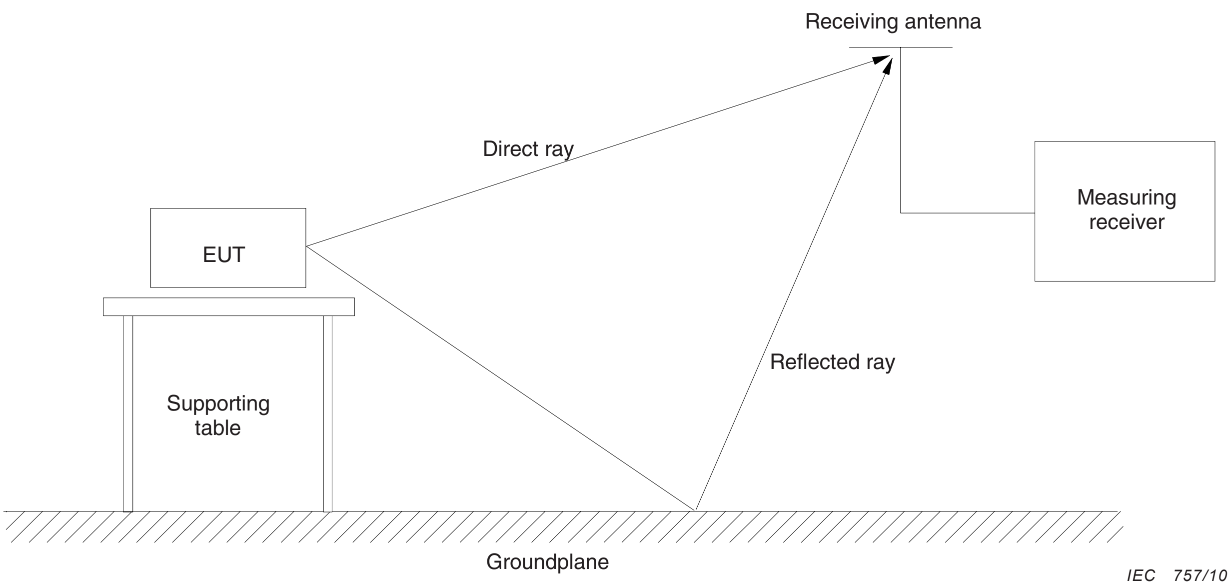


Figure 6 – Concept of electric field strength measurements made on an open-area test site (OATS) or semi-anechoic chamber (SAC) showing the direct and reflected rays arriving at the receiving antenna

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

7.3.4 Measurement distance

An EUT subject to a radiated disturbance limit at a specified distance should be measured at that distance unless to do so would be impractical because of equipment size, etc. The measurement distance is the distance between the projection of closest point of the EUT to the antenna and the projection of the calibration reference point of the antenna on the ground plane. If the antenna reference point is not specified in the antenna calibration report, for log-periodic antennas the reference point is a point along the horizontal antenna boom midway between the dipole elements that correspond to a half wavelength at the centre frequency of antenna frequency range.

NOTE The centre frequency is defined by: $\log(f_{centre}) = (\log f_{min} + \log f_{max})/2$; $f_{centre} = 10^{\log(f\ centre)}$.

A distance of 10 m is preferred at most outdoor sites since at this distance the expected level of the disturbance being measured is sufficiently above the general ambient noise level to permit useful testing. Distances of less than 3 m or greater than 30 m are not generally used. If a measurement distance other than the specified distance is necessary, the results should be extrapolated using the procedures specified in the product standards. If no guidance is given, suitable justification for extrapolation shall be provided. In general, extrapolation does not follow a simple inverse distance law.

Where possible, measurement should be made in the far field. The far-field region may be defined by the following conditions. The measurement distance d is selected so that:

a) $d \geq \lambda/6$. At this distance $E/H = Z_0 = 120\ \pi = 377\ \Omega$, that is electrical and magnetic field strength components are perpendicular to each other, and the measurement error is in the order of 3 dB if the EUT is regarded as being a tuned dipole antenna; or
b) $d \geq \lambda$, a condition for a plane wave, where the error is in the order of 0,5 dB if the EUT is regarded as a tuned dipole antenna; or
c) $d \geq 2D^2 / \lambda$, where D is the largest dimension of either the EUT or the antenna determining the minimum aperture for the illumination of the EUT, which applies to cases, where $D >> \lambda$.

7.3.5 Antenna height variation

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

7.3.6 Product specification details

7.3.6.1 General

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

7.3.6.2 Test environment

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

The electromagnetic environment needs special consideration to ensure accurate disturbance measurements. The ambient radio noise and signal levels measured at the test site with the EUT de-energized should be at least 6 dB below the limit. It is recognized that this is not always realizable at all frequencies. However, in the event that the measured levels of the ambient plus EUT radio noise emissions are not above the limit, the EUT shall be considered to be in compliance with the limit. See 6.2.2 and Annex A for further guidance about ambient levels and resulting measurement errors.

A2 If the ambient field-strength level at frequencies within the specified measurement ranges, at the specified measurement distance, exceeds the limit(s), the following alternatives may be used to show compliance of the EUT:

a) Perform measurements at a closer distance and extrapolate results to the distance at which the limit is specified. Extrapolate the results using one of the following methods:

   1) determine L_2 corresponding to the close-in distance d_2 by applying the relation $L_2 = L_1(d_1/d_2)$, where L_1 is the specified limit in μV/m at the distance d_1;

      NOTE This extrapolation method can only be used when both d_1 and d_2 are in the far-field zone of the EUT at all frequencies of measurement.

   2) use the formula as recommended by the product standard;

   3) determine the limit L_2 at a distance d_2 applying an extrapolation formula verified by measurements at no less than three different distances.

b) In the frequency bands where the ambient noise values are exceeded (measured values higher than 6 dB below the limit), the disturbance values of the EUT may be interpolated from the adjacent disturbance values. The interpolated value shall lie on the curve describing a continuous function of the disturbance values adjacent to the ambient noise. A2

A2 c) A2 perform measurements in critical frequency bands during hours when broadcast stations are off the air and the ambients from industrial equipment are lower;

A2 d) A2 compare the amplitude of the EUT disturbance at the frequency under investigation with the amplitude of the disturbance on adjacent frequencies, in a shielded room or absorber-lined shielded room. The amplitude of the EUT disturbance at the frequency under investigation can be estimated by measuring the amplitude of the adjacent frequency disturbance and making a comparison;

A2 e) A2 consider the directions of strong ambient signals in orienting the axis of an A2 OATS A2 , so that the orientation of the receiving antenna on the site discriminates against such signals as far as possible;

A2 f) A2 use a narrower instrument bandwidth for narrowband disturbances from the EUT occurring near an RF ambient when both are within the standard bandwidth.

7.3.6.3 Configuration of A2 EUT

The EUT operating conditions and arrangement are detailed in 6.4.

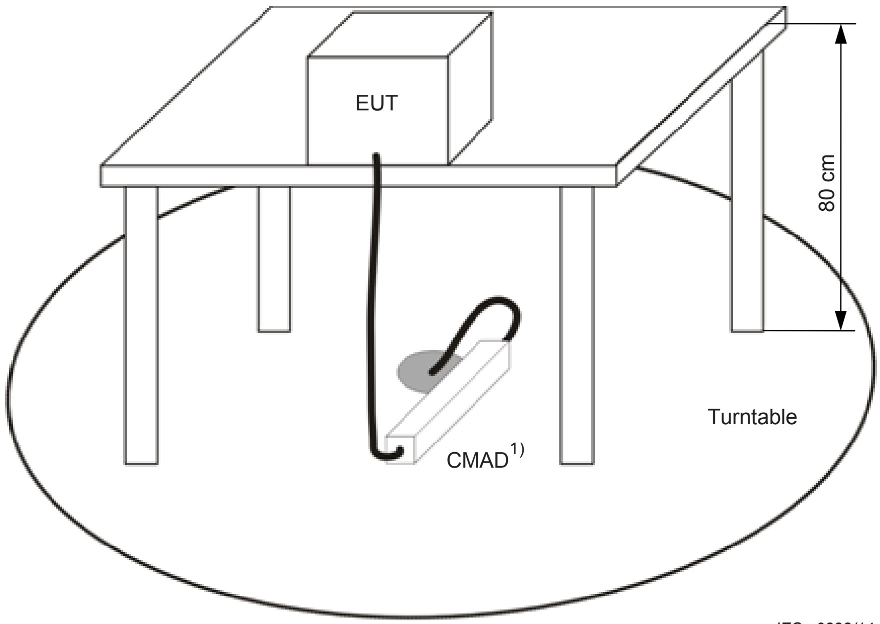
Ferrite clamp type CMADs are used to reduce the influence of cables outside the test volume on radiated disturbance measurement results. If CMADs are used, the cable leaving the test volume shall enter the CMAD at the point where it reaches the ground plane as shown in Figure 22. The CMAD shall always be placed flat on the ground plane. The part of the cable between the exit point of the CMAD and the exit point of the turntable shall be kept as short as possible. Each cable shall be treated with a separate CMAD. Cables with diameters larger than the cable openings of commercially available CMADs do not have to be treated with CMADs.

NOTE 1 In order to avoid saturation, high common mode current power cables (e.g. the output port of inverters) should not be treated with CMADs unless the CMADs in use are specifically designed for high common mode currents. A2

A2 For EUTs with up to three cables leaving the test volume, each cable shall be treated with a CMAD during radiated disturbance measurements. This requirement applies to any type of cable (e.g. power, telecommunication, and control). For a test set-up with more than three cables leaving the test volume, only the three cables from which the highest emission is expected need to be equipped with CMADs. The cables on which the CMADs have been applied shall be documented in the test report.

NOTE 2 The limitation of the number of CMADs is discussed in [10]. In comparing large versus small size EUTs, as well as EUTs with one versus two cables, the author concluded that a small EUT with only one cable leaving the test volume is worst case. The author's investigation covered application of CMADs to tabletop equipment with three cables or less.

General information on the purpose and application of ferrite-type CMADs is provided in 4.9.1 of CISPR/TR 16-3 [2].



1) CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report.

Figure 22 – Position of CMAD for table-top equipment on OATS or in SAC A2

7.3.7 Measurement instrumentation

The measurement instrumentation, including antennas, shall conform to the relevant requirements in CISPR 16-1-1 and CISPR 16-1-4.

7.3.8 Field-strength measurements on other outdoor sites

Outdoor test sites similar to an open-area test site but without any metal ground plane may be prescribed for some products, for practical reasons, e.g. ISM equipment and motor vehicles. The provisions given in 7.3.4 to 7.3.7 shall remain applicable.

7.3.9 Measurement uncertainty for OATS and SAC

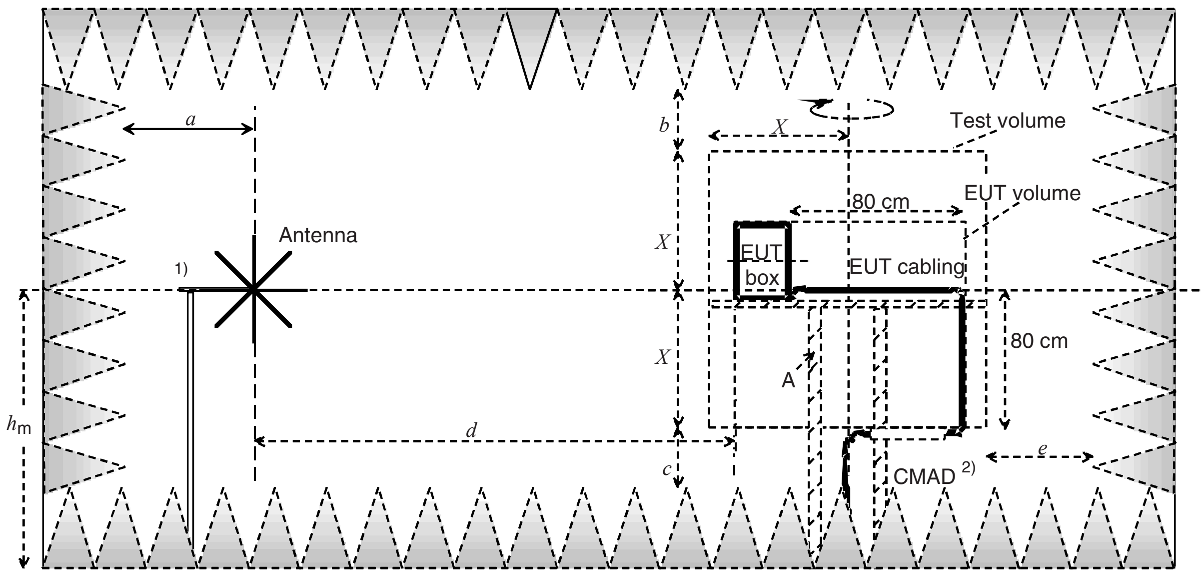
General and basic considerations about uncertainties for emission measurements are given in CISPR 16-4-1. Uncertainty aspects specific to radiated emission measurements on an OATS or SAC (30 MHz to 1 GHz) are given in CISPR 16-4-2.

7.4 Fully-anechoic room measurements (30 MHz to 1 GHz)

7.4.1 Test set-up and site geometry

The same type of antenna shall be used for EUT emission testing as the receive antenna used for the FAR site validation testing. The antenna height is fixed at the geometrical middle height of the test volume. Measurement will be done in horizontal and vertical polarization of the receive antenna. Emission should be measured while the turntable rotates with the EUT in each of at least three successive azimuth positions (0°, 45°, 90°), when continuous rotation is not required. Figure 7 illustrates the typical FAR site geometry, and the relevant dimensions.

The EUT shall be placed on a turntable. Figure 7, Figure 8 and Figure 9 explain the different dimensions within the FAR. The turntable, antenna mast and supporting floor shall be in place during the site validation procedure, and consist largely of material transparent to electromagnetic waves. The distances *a*, *b*, *c* and *e* may be limited by the size of the test volume. The level of the bottom plane (absorber height plus *c*) will be the level for floor-standing equipment (transport pallet height will be outside the test volume).



A turntable and EUT support fixture;

2*X* 1,5 m, 2,5 m, 5 m – corresponds to test distance used (3 m, 5 m, or 10 m respectively);

h_m middle level of the test volume;

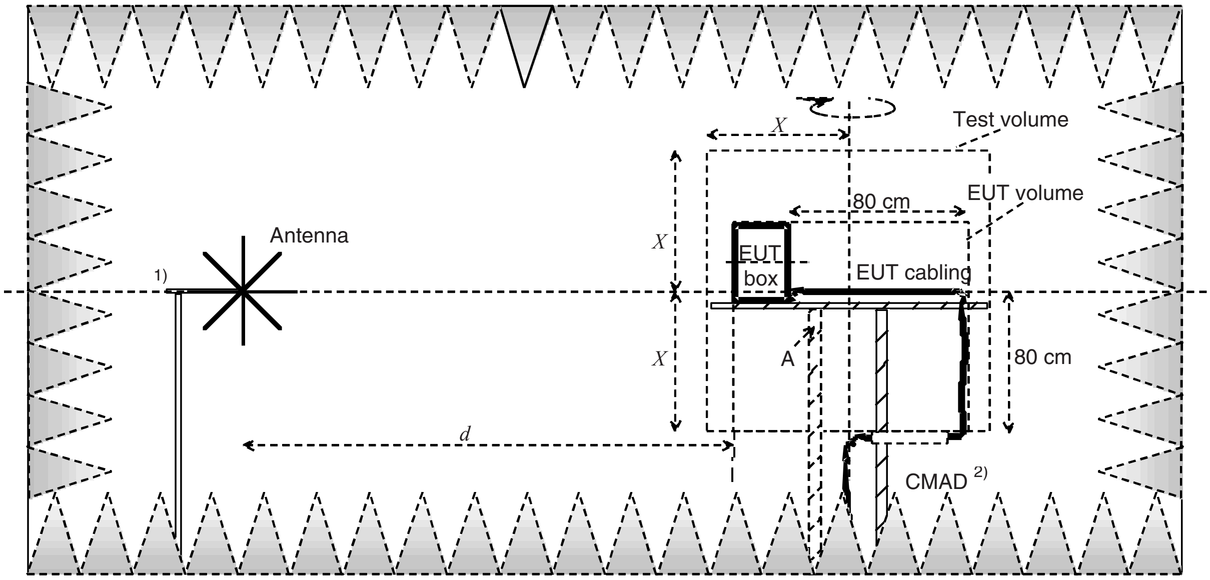
a, *b*, *c*, *e* ≥ 0,5 m recommended (≥ 1 m is more convenient), the actual value is consistent with the FAR validation procedure of CISPR 16-1-4;

d 3 m, 5 m, or 10 m.

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

2) [A2) CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report. (A2]

Figure 7 – Typical FAR site geometry, where *a*, *b*, *c*, *e* depend upon the room performance



A turntable and EUT support fixture;

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

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

1) The antenna cable layout shall be the same as in the site validation procedure (see Figure 7).

2) [A2⟩ CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report. ⟨A2]

Figure 8 – Typical test set-up for table-top equipment within the test volume of a FAR

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

The correction factor, C_{dr} in dB, in Equation (5), may be added to the field strength in order to reduce its uncertainty. In the calibration procedure for the antenna a phase correction factor C_{dr} is measured for each frequency. The measurement procedure is defined within the antenna calibration, or calculated from the mechanical spacing of the log-periodic elements along with the antenna factor F_a. The two factors (C_{dr}, and F_a) in dB are added to the output voltage of the antenna to get the field strength, per Equation (6). If a phase centre correction is not included, an additional term must be included in the uncertainty budget.

$$C_{dr} = 20\log\left[\left(d + P_f - r\right)/d\right] \quad (5)$$

The field strength is given by:

$$E_f = V_f + F_\mathrm{a} + C_{dr} \quad (6)$$

where

f is the frequency (MHz);

d is the required separation point from the EUT boundary to the reference point on the antenna (m);

P_f is the phase centre position as a function of frequency, (m from tip of antenna);

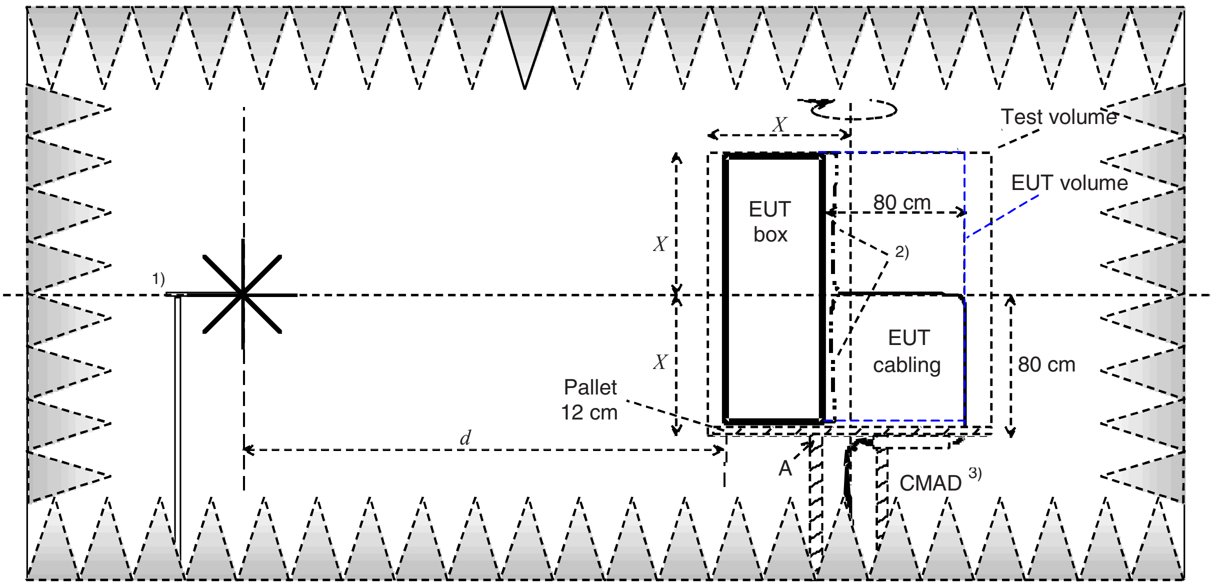
r is the distance of the reference point on the antenna from the antenna tip (m);

E_f is the E-field at distance d from the source [dB(μV/m)];

V_f is the voltage at the output of the antenna at frequency f [dB(μV)];

C_{dr} is the phase centre correction factor (dB);

F_a is the antenna factor (free space) for the E-field at the phase centre [dB(m^{-1})].



A turntable and EUT support fixture

2X 1,5 m, 2,5 m, 5 m

d 3 m, 5 m or 10 m for 3 m, 5 m, or 10 m test distance, respectively

Pallet of 12 cm (10 cm to 14 cm) is a compromise between metal- and wooden ground plane.

1) The antenna cable layout shall be the same as in the validation procedure (see Figure 7).

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

3) [A2) CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report. (A2]

Figure 9 – Typical test set-up for floor-standing equipment within the test volume of a FAR

7.4.2 EUT position

Figure 8 and Figure 9 illustrate test set-ups in a FAR for typical table-top and floor-standing EUTs, respectively. The EUT shall be configured, installed, arranged and operated in a manner consistent with typical applications. The entire EUT shall fit in the test volume. Associated equipment that is required to exercise the EUT but does not form part of the EUT shall be located outside the screened room.

Interface cables shall be connected to each type of interface port of the EUT. If the EUT consists of separate devices, the space between the devices shall be in the normal configuration, but with 10 cm separation if possible. Interconnecting cables shall be bundled. The bundle shall be of length 30 cm to 40 cm and longitudinal to the cable.

To improve the measurement repeatability, the following guidelines shall be applied:

a) The EUT (including the cables laid out according to 7.4.3) shall be placed so that its centre is at the same height as the centre of the test volume. A non-conductive support of a suitable height may be used to achieve this.

b) Where it is not physically possible to elevate a large EUT to the centre of the test volume (Figure 7 and Figure 8), the EUT may remain on a non-conductive transport pallet during the test (Figure 9). The height of the pallet shall be recorded in the test report.

The installation specifications for some floor-standing equipment require the unit to be installed and bonded directly to a conductive floor. The following considerations apply for testing of floor-standing equipment in a FAR: if FAR test results for floor-standing equipment intended to be installed and bonded directly to a conductive floor show non-compliance with an emissions limit applicable to FAR sites, actual emissions may be lower if the EUT were tested on a ground plane that better simulates the final installation environment. This is particularly true if the emissions are at a frequency below 200 MHz, horizontal polarization, and the source of emissions is from a location on the equipment that would correspond to a height above ground of 0,4 m or less in a typical installation. The reader is advised that prior to a determination of non-compliance based on FAR measurements, additional investigation in a ground plane test environment (i.e. an open-area test site or semi-anechoic chamber) is recommended, to better simulate the final intended installation condition for the equipment.

7.4.3 Cable layout and termination

In EMC testing, the reproducibility of measurement results is often poor due to differences in cable layout and termination, when one single EUT is measured at various test-sites. The following listed items are general conditions for the test set-up in order to provide good reproducibility (see Figure 8 and Figure 9). Ideally all radiation to be measured should only be emitted from the test volume. The cables used during the test shall be in accordance with manufacturer‘s specifications. The EUT may employ non-terminated cables if cable terminations are not available. The specifications of the cables and terminations used during testing shall be clearly described in the test report.

a) The cables that are connected to the EUT and auxiliary equipment or power supply shall include a length of 0,8 m run horizontally and 0,8 m run vertically (without any bundling) inside the test volume (see Figure 8 and Figure 9). Any cable length in excess of 1,6 m with a relative tolerance of ± 5 % shall be routed outside the test volume.

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

c) Cables that are not exercised through associated equipment during the test must be appropriately terminated:

   1) coaxial (shielded) cables with coaxial terminator with correct impedance (50 Ω or 75 Ω);

   2) shielded cables with more than one inner wire must have common mode (line to reference earth/ground) and differential-mode (line to line) termination in accordance with the manufacturer′s specifications;

   3) unshielded cables must have differential mode termination as well as common-mode termination in accordance with the manufacturer′s specifications.

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

e) [A2) The test set-up, including cable layout and details of attached cables and terminations, are specified in the different product standards. (A2]

[A2) f) Ferrite clamp type CMADs are used to reduce the influence of cables outside the test volume on radiated disturbance measurement results. The cable leaving the test volume shall enter the CMAD at the point where it reaches the bottom of the test volume (turntable) as shown in Figures 7, 8 and 9. Each cable shall be treated with a separate CMAD. Cables with diameters larger than the cable openings of commercially available CMADs need not be treated with CMADs.

NOTE In order to avoid saturation, high common mode current power cables (e.g. output port of inverters) should not be treated with CMADs, unless the CMADs in use are specifically designed for high common mode currents.

For EUTs with up to three cables leaving the test volume, each cable shall be treated with a CMAD during radiated disturbance measurements. This requirement applies to any type of cable (e.g. power, telecommunications and control). For a test set-up with more than three cables leaving the test volume only the three cables from which the highest emission is expected need to be equipped with CMADs. The cables on which the CMADs have been applied shall be documented in the test report.

General information on the purpose and application of ferrite-type CMADs is provided in 4.9.1 of CISPR/TR 16-3 [2]. (A2]

Due to the different nature of the many possible EUTs, product standards may deviate considerably from the requirements of this subclause (e.g. 10.5 of CISPR 22 [3])[2].

7.4.4 Measurement uncertainty for FAR

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1. Conditions for the use of alternative test methods are given in CISPR 16-4-5. An example of an uncertainty budget for an emission measurement at a 3 m distance in a FAR is given in CISPR 16-4-2.

7.5 Radiated emission measurement method (30 MHz to 1 GHz) and radiated immunity test method (80 MHz to 1 GHz) with common test set-up in semi-anechoic chamber

7.5.1 Applicability

As an alternative to different test set-ups for radiated emissions and radiated immunity testing, at the discretion of product committees, testing to both requirements may be performed using a common EUT arrangement in accordance with the provisions of this clause. The test arrangement described in this clause is applicable when radiated emissions and immunity testing of the EUT using the same configuration and test set-up is technically justified. This test arrangement is considered to be most applicable to EUTs of simple configuration, e.g. single enclosure, combination of small enclosures, less than five cables connected to the EUT. This alternative test arrangement is allowed for EUTs whose product emissions standards permit radiated emission tests at 3 m separation distance.

The radiated immunity test may be performed with absorbing material covering portions of the ground plane between the EUT and the transmitting antenna, if necessary to achieve field uniformity, as described in IEC 61000-4-3 (i.e. absorber-lined SAC, analogous to absorber-lined OATS). For emission measurements, the normalized site attenuation characteristics of the SAC without the ground-plane absorber shall satisfy the requirements of CISPR 16-1-4.

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2 Figures is square brackets refer to the Bibliography.

7.5.2 EUT perimeter definition and antenna-to-EUT separation distance

Radiated emission and immunity tests shall be made with the receive or transmit antenna located at a horizontal distance of 3 m plus half of the maximum width of the EUT being tested, measured from the centre of the EUT. The antenna reference point used when determining its distance from the EUT is the identified reference point. However, if the reference point is not specified, the reference point is a point along the horizontal antenna boom midway between the dipole antenna elements that correspond to a half wavelength of the upper and lower frequency limits to be evaluated.

NOTE For a log-periodic antenna, the manufacturer may specify the reference point.

The EUT perimeter is defined by the smallest virtual (imaginary) rectangle encompassing the EUT. All intersystem cables shall be included within this perimeter (see Figure 10). Each edge of this perimeter shall lie in one of the four face planes of the EUT, co-planar with (and possibly residing within) the uniform field areas (UFAs) calibrated for immunity tests, depending upon the horizontal test distance.

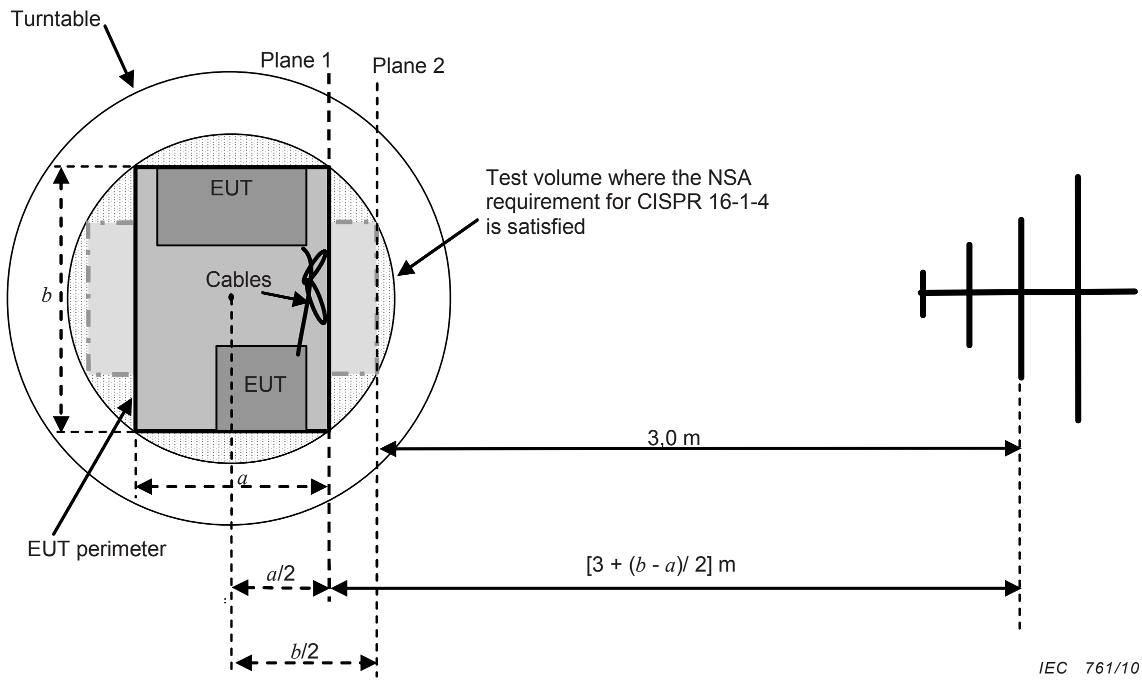


Figure 10 – Positions of reference planes for uniform field calibration (top-view)

7.5.3 Uniform test volume

The uniform test volume is defined by the following conditions.

- The EUT and its auxiliary equipment (AuxEq) (e.g. peripherals and cables) shall fit into a test volume where the site validation requirements of CISPR 16-1-4 are fulfilled. Refer to the site validation procedure for alternative test sites for use in emission measurements of CISPR 16-1-4;
- The EUT and its AuxEq shall fit into a test volume that allows each of the faces of the EUT and its AuxEq to be aligned with the uniform field area according to the requirements of IEC 61000-4-3 and as described in this subclause.

Evaluation of EUTs having unequal or non-symmetric boundaries at two antenna separation distances necessitate uniform field area calibrations according to the requirements of IEC 61000-4-3. In the example shown in Figure 10, this is at the plane with length b along the front face of the EUT (0° azimuth) and the plane with length a along the side face of the EUT (90° azimuth).

To accommodate EUTs with a maximum width of 1,5 m, the uniform field area may be calibrated for the two conditions:

- in a plane orthogonal to the axis of the antenna through the centre of the turntable;
- in a plane orthogonal to the axis of the antenna 0,75 m in front of the centre of the turntable, perpendicular to the measurement axis.

A linear interpolation can be performed to test any EUT whose exposed front is between the two calibrated UFAs. It is presumed that:

- the -0 dB to +6 dB criteria complies at the number of points defined by IEC 61000-4-3 for each of the two surfaces, and
- the average field strengths of the points satisfying the -0 dB to +6 dB criterion in the two UFAs are inversely proportional to the antenna-to-UFA distance when applying a constant forward power to the antenna.

Designate P_{c1} as the forward power (logarithmic scale) for the UFA at the centre of the turntable, evaluated by either the calibration with constant field strength or the calibration method with constant power, and P_{c2} as the corresponding forward power for the UFA at 0,75 m in front of the centre of the turntable. The required forward power to illuminate an EUT surface can be calculated by linear interpolation from P_{c1} and P_{c2} and the corresponding distances (also in logarithmic scale) to the antenna. For other measurement details and descriptions, refer to 6.2 of IEC 61000-4-3 calibration of field.

For EUT perimeter dimensions that differ by 20 % or less of the 3 m separation distance (that is, 0,6 m or less), only a single uniform field area calibration is required at the separation distance corresponding to Plane 1 in Figure 10 (the widest face of the EUT).

NOTE When using the method described in the preceding paragraph, two faces of the EUT will be tested at a higher immunity field-strength level due to their closer distance to the transmitting antenna.

The EUT perimeter, including the connecting cables, shall fit within the test volume where the site validation requirement is satisfied. For the common emission/immunity set-up, the facility must be calibrated at two vertical planes corresponding to the minimum and maximum dimensions of the EUT perimeter at 0°, 90°, 180° and 270° to the EUT faces. The types of equipment to be tested in the facility may be considered for selection of the two plane locations.

If floor absorbers are used to achieve the field uniformity criterion, these absorbers shall be placed between the transmitting antenna and Plane 2. If only one plane is calibrated (that is, an EUT with a difference of the two boundary dimensions being less than 0,6 m), the floor absorbers, when used, shall be placed between the transmitting antenna and the calibrated plane.

7.5.4 Specifications for EUT set-up in common emissions/immunity test setup

The tests shall be performed with the equipment configured as closely as possible to its typical, practical operation. Unless stated otherwise, cables and wiring shall be as specified by the manufacturer and the equipment shall be in its housing (or cabinet) with all covers and access panels in place. Any deviation from normal EUT operating conditions shall be included in the test report. The specifications of 7.3.6.3 apply. The EUT (on a non-conductive support structure, where applicable) shall be placed on a remotely operated turntable, as specified in 7.3.6.3, to allow the EUT to be rotated.

The height of the EUT above the ground plane shall be in accordance with the following requirements.

- Table-top equipment is placed on a non-conductive setup table with height 0,8 m ± 0,01 m, see 7.3.6.3. CISPR 16-1-4 specifies the method to determine the impact of the non-conductive set-up table on test results.
- Floor-standing equipment is placed on a non-conductive support, as specified in the applicable product standard. If there are no EUT height placement requirements in the product standard, the EUT shall be placed on a non-conductive support at a height of 5 cm to 15 cm above the ground plane.

Equipment designed for wall-mounted operation shall be tested as table-top equipment. The orientation of the EUT shall be consistent with that of normal operation (that is, positioned as normally installed).

Interface cables, loads, and devices should be connected to at least one of each type of the interface ports of the EUT and, where practical, each cable shall be terminated in a device typical for its actual use. Where there are multiple interface ports of the same type, a typical number of these devices shall be connected to devices or loads. It is sufficient to connect only one of the loads, provided that it can be shown, for example by preliminary testing, that the connection of further ports would not significantly increase the level of disturbance (that is, more than 2 dB) or significantly degrade the immunity level. The rationale for the configuration and loading of ports shall be documented in the test report.

The number of additional cables should be limited to the condition where the addition of another cable does not decrease the margin by a significant amount (for example, 2 dB) with respect to the limit. In some cases the optimum arrangement of features, loads, interface types, and cables for emissions and immunity tests are different, which may result in the need for some reconfiguration of the EUT within the confines of the uniform EUT arrangement.

The cable layout and termination shall be according to the following requirements.

A1 • The cables shall be oriented so that vertically- and horizontally-polarized radiation fields are not excluded. The cable layout rules and cable lengths defined in the applicable product emission and immunity standards shall be applied.However, in case of conflicting requirements, the layout and maximum cable lengths defined in the product emission standard shall be used. Fulfilling the rules can be accomplished by applying the cable placement rules of the emissions standard and exposing a minimum length of 1 m of cable, with a mix of horizontal or vertical parts, to the electromagnetic field during immunity testing (unless the manufacturer's specifications require shorter cables). Excess cable lengths should be bundled in the approximate centre of the length of the cable to form a bundle 30 cm to 40 cm in length. If no information is provided about cable layout in the product emission standard, the following arrangement is applied: A1

A2 – A2 For a table-top EUT (Figure 11 and Figure 12), the cables leaving the uniform test volume (that is, those that connect the EUT to the outside world) shall be exposed to the electromagnetic field according to Figure 11 and Figure 12 for a total length of 1 m (± 0,1 m), and then extended vertically down towards the floor (with a minimum length of 0,8 m imposed by the EUT table height). Interconnecting cables that hang from the table shall be at a minimum distance of 0,4 m (±0,04 m) from the ground plane. If cables that hang closer than 40 cm to the ground plane cannot be shortened to the appropriate length, the excess cable shall be folded back and forth to form a bundle 30 cm to 40 cm long. If the maximum length declared by the manufacturer for certain cables does not allow a one meter horizontal cable layout, including a length to get to the ground plane for table-top products (placed on the 0,8 m height table), the horizontal layout shall depend on the length of cable in excess of 0,8 m. Bundling is not required.

A2 – A2 For a floor-standing EUT (Figure 13 and Figure 14), cables leaving the uniform test volume shall be arranged with a length of at least 0,3 m run horizontally within the test volume and with a vertical run according to typical, normal use (depending on the height above the floor of the I/O port). Horizontal cables shall be insulated from the ground planes by a minimum height of 10 cm for the entire length of the cable that is intended to be laid out along the floor.

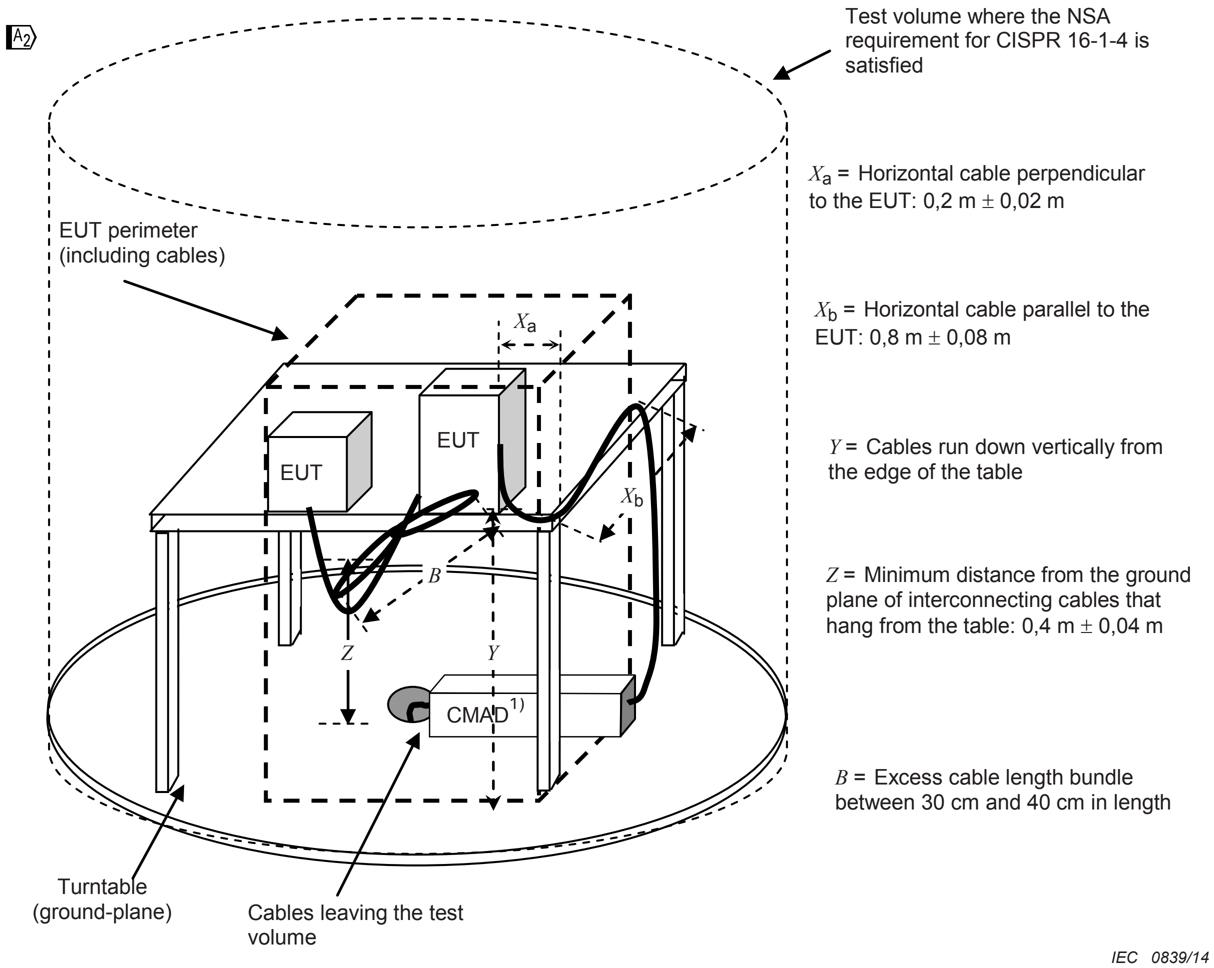
Cabling between enclosures of the EUT shall be treated as follows:

- The manufacturer's specified cabling types and connectors shall be used.
- If the manufacturer's specification requires a cable length of less than or equal to 3 m, then the specified length shall be used. The cables shall be exposed for a length of 1 m (± 0,1 m) and the excess shall be folded back and forth, forming a bundle 30 cm to 40 cm long, for table-top equipment (see Figures 11 and 12) and approximately 1 m for floor-standing equipment (see Figures 13 and 14).
- If the specified length is greater than 3 m or is not specified, then the illuminated length shall be 1 m. The excess cables shall be extended outside the test volume.
- EUT combinations of table-top equipment and floor-standing equipment shall be arranged according to the set-up of each individual equipment configuration and the interconnecting cables between table-top equipment and floor-standing equipment shall be according to these rules.
- For the cables not terminated into auxiliary equipment, differential- and common-mode terminations should be simulated to represent the auxiliary equipment that would be connected to the cables and represent the required functional impedance.
- Cables not connected to another device may be terminated as follows (see also 7.3.6.3).
  - Coaxial shielded cables shall be terminated with a coaxial termination (usually 50 Ω or 75 Ω)
  - Shielded cables with more than one inner wire should have common- and differential-mode termination according to the EUT manufacturer's specifications. This common-mode termination is to be connected appropriately between the inner wires or their differential-mode termination and cable shield. If no information is available about the common-mode terminations, 150 Ω common-mode terminations should be used.
  - Unshielded cables must have differential-mode termination according to the manufacturer's specifications.
  - All cables that have been shortened in respect to their maximum lengths declared by the manufacturer and provided with artificial terminations for testing convenience, according to this paragraph, should also be provided with additional 150 Ω common-mode terminations to the test chamber wall or floor.

The following items should be considered with 7.3.6.3.

- If the EUT needs associated equipment (AE) to operate properly, special care must be taken to ensure that AE does not affect the radiated emissions measurements or the radiated immunity tests. AE may be located outside the anechoic chamber during testing if proper connecting interfaces are available on the chamber shielding. Measures to prevent RF-leakage into or out of the anechoic chamber through the interconnection cable may be necessary.
- Other methods or equipment used to suppress unwanted emissions from AE shall be located outside the test chamber or beneath the raised floor.
- The test set-up, including cable layout, specifications of attached cables and terminations, use of CMAD(s) on cables leaving the test volume, and other measures taken to suppress emissions from AE outside the test volume, shall be clearly described in the test report.

A2›



1) CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report.

Figure 11 – Test set-up for table-top equipment ‹A2

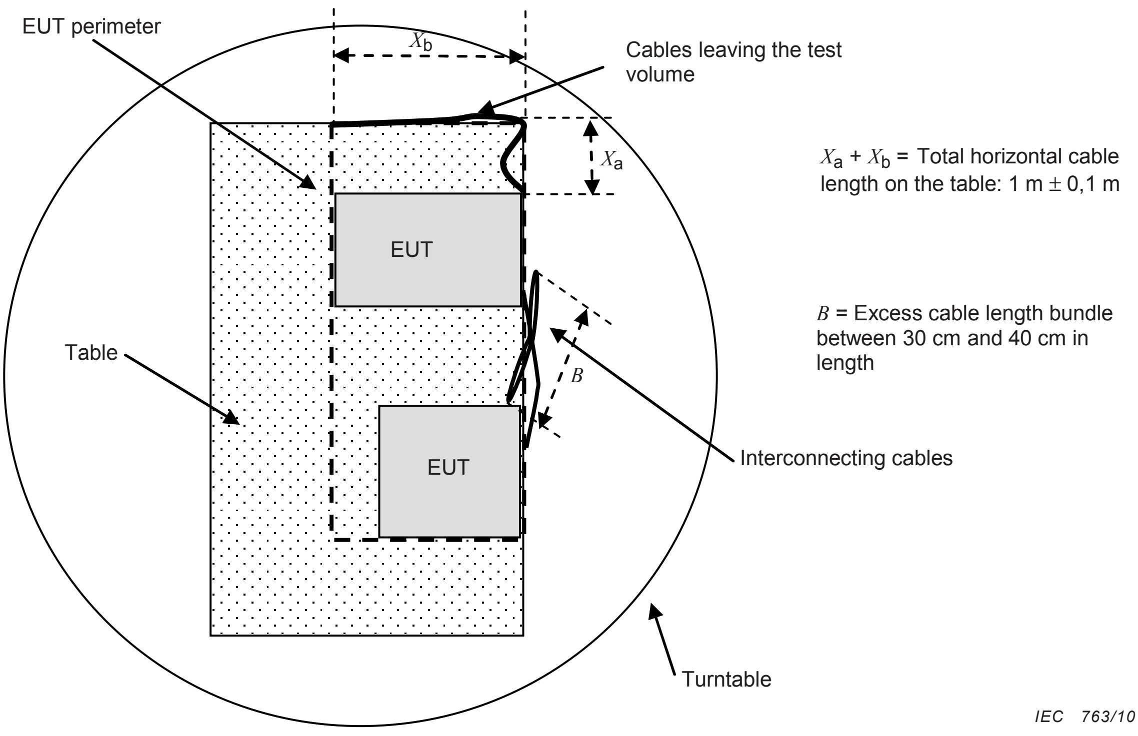
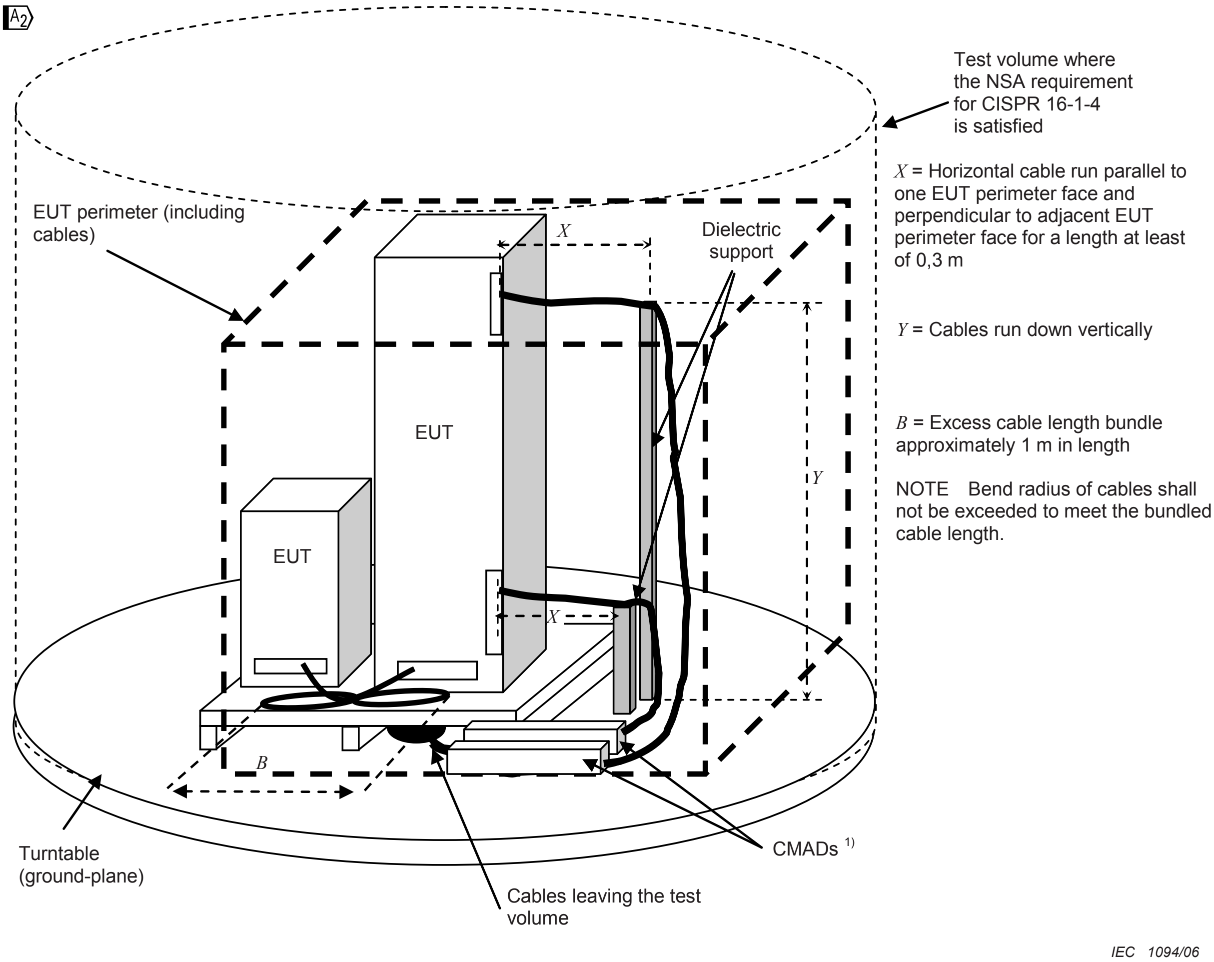


Figure 12 – Test set-up for table-top equipment – Top view

[A2]



1) CMADs shall comply with the relevant specifications of CISPR 16-1-4; their use shall be documented in the test report.

Figure 13 – Test set-up for floor-standing equipment [A2]

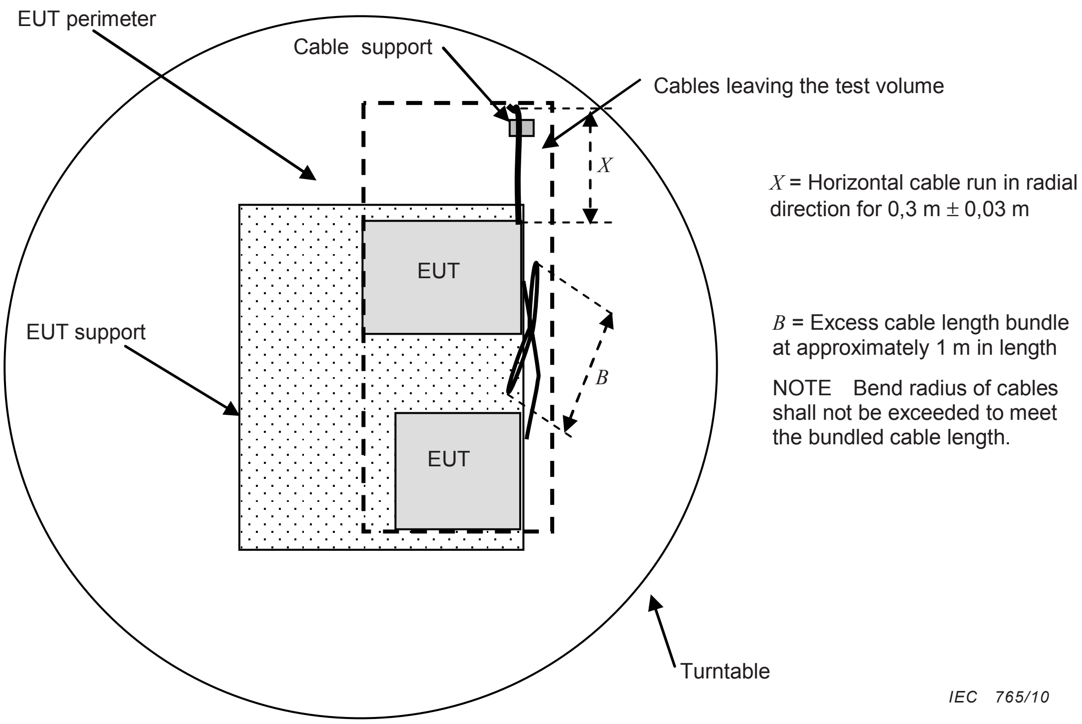


Figure 14 – Test set-up for floor-standing equipment – Top view

7.5.5 Measurement uncertainty for common emission/immunity set-up and method

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.6 Fully-anechoic room and absorber-lined OATS/SAC measurements (1 GHz to 18 GHz)

7.6.1 Quantity to measure

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

In some standards, emission limits above 1 GHz for equipment are expressed in terms of effective radiated power (P_{RE}) in dB(pW). Under free-space far-field conditions, the equation to convert P_{RE} into field strength, in dB(µV/m), at a 3 m distance is:

$$E_{3\mathrm{m}} = P_{\mathrm{RE}} + 7{,}4 \tag{7}$$

For distances d, in m, other than 3 m:

$$E_d = P_{\mathrm{RE}} + 7{,}4 + 20\log\left(\frac{3}{d}\right) \tag{8}$$

7.6.2 Measurement distance

The field strength emitted by the EUT is measured at a preferred distance of 3 m. The measurement distance, d, is the horizontal distance between the periphery of the EUT and the receive antenna reference point (see Figure 15). The EUT encompasses all portions of the EUT, including cable racks and support equipment and a minimum cable length of 30 cm.

Other distances may be used in practical situations, i.e.:

– shorter distances in the case of high ambient noise, or to reduce the effect of unwanted reflections, but care should be taken to ensure the measurement distance is greater than or equal to $D^2/(2\lambda)$;
– greater distances for large EUTs to allow the antenna beam to encompass the EUT.

NOTE Because dominant components of the EUT disturbance signals may be assumed to be incoherent and radiated from a point source, the minimum distance mentioned above, i.e. $D^2/(2\lambda)$, is to be established using the measuring antenna dimensions, and not the EUT dimensions.

If measurements are made at a distance other than 3 m (see note above), the measurement distance shall be greater than or equal to 1 m and less than or equal to 10 m. In such a case, the measurement data is to be adjusted to a 3 m distance, assuming free-space propagation. Users are advised that comparison of measurements at different distances and extrapolation of results typically will not correlate as well as measurements made at the same distance. Standards or specifications that reference this test method should identify a preferred measurement distance.

7.6.3 Set-up and operating conditions of the equipment under test (EUT)

As a general guideline, test set-ups and operating conditions of the EUT shall be the same as those used below 1 GHz. Whenever possible, the test set-up should be representative of the most typical configuration of the EUT (table-top, floor-standing, rack-mounted, wall-mounted, etc.).

The test set-up should also consider that for measurements above 1 GHz absorbers are typically required on the floor between the antenna and EUT. Whenever practical, for emission measurements above 1 GHz the EUT should be raised above the height of the absorbers. If it is not possible to raise the entire EUT above the absorbers (i.e. for rack-mounted or floor-standing equipment), efforts should be made to configure the EUT (within a rack or chassis, for example) such that the radiating elements are located above the absorbers. The EUT shall be located in the test volume established during site validation, as described in CISPR 16-1-4. If it is not practical and safe to raise the EUT or its radiating elements above the absorber height, the maximum extent of the EUT that is permitted to be located below the highest point of the absorbers is 30 cm (see 7.6.6.1 and Figure 15).

The actual EUT configuration and set-up used shall be documented in the test report with photographs or diagrams clearly showing the location of the EUT with respect to the facility floor or turntable surface, absorber placement on the floor (height and location) and receive antenna location.

7.6.4 Measurement site

The measurement site shall comply with the requirements described in CISPR 16-1-4.

7.6.5 Measurement instrumentation

The measurement instrumentation shall comply with the requirements described in CISPR 16-1-1 and CISPR 16-1-4.

Measurements to verify compliance with a peak limit shall be conducted with the peak measuring spectrum analyzer or receiver using a measurement bandwidth of 1 MHz (impulse bandwidth) as defined CISPR 16-1-1.

Measurements to verify compliance with an average limit shall be conducted with a peak measuring spectrum analyzer using a measurement bandwidth of 1 MHz (impulse bandwidth) and a reduced video bandwidth, set as defined in CISPR 16-1-1. The value of video bandwidth required for an average measurement shall be less than the lowest spectral component of the input signals to be measured.

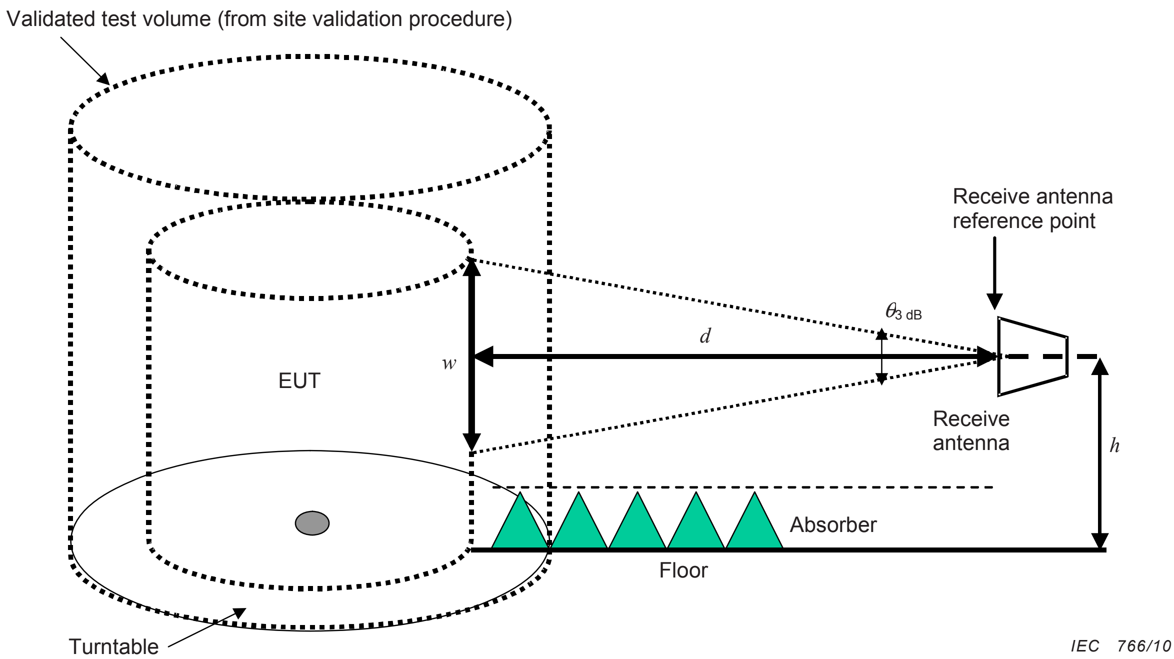
NOTE A spectrum analyzer can be used to perform average measurements by setting the display mode to linear and the video bandwidth to a value that is lower than the lowest spectrum component of the input signal to be measured. For example, if the input signal has a 1 kHz pulse repetition frequency (PRF), for a video bandwidth less than 1 kHz, only the d.c. component of the signal (i.e. the average value) will pass through the video filter.

The use of other types of linear average detectors that comply with these requirements is allowed. In general, the spectrum analyzer shall be set to linear display mode when performing average measurements, not logarithmic display mode. The sweep time of the spectrum analyzer shall be increased, due to the use of narrower video bandwidths, to ensure accurate measurement results. The logarithmic mode is permitted for average measurements when the specification limits assume a logarithmic detector will be used.

7.6.6 Measurement procedure

7.6.6.1 General description of the radiated field measurement method above 1 GHz

The radiated field measurement method above 1 GHz is based on measurement of the maximum electric field emitted from the EUT, with a set-up as shown in Figure 15.



NOTE The anechoic material placed on the ground plane is for illustration purposes only. Consult CISPR 16-1-4 for more detailed guidance about placement of absorber to comply with the site validation requirements.

Figure 15 – Measurement method above 1 GHz, receive antenna in vertical polarization

The following descriptions apply to the parameters and terms given in Figure 15.

- Validated test volume: the volume evaluated during the site validation procedure (see CISPR 16-1-4). Typically, this determines the largest diameter EUT that can be tested in the facility.
- EUT (volume): the smallest diameter cylinder that will fully encompass all portions of the actual EUT, including cable racks and a minimum length of 30 cm of cables. The EUT that is located within this cylinder must be capable of rotating about its centre (typically by a remotely controlled turntable). The EUT must be located within the validated test volume. A maximum of 30 cm of w (see definition of w below) may be below the height of absorbers on the floor only when the EUT is floor-standing and cannot be raised above the height of the absorbers (see 7.6.3).
- $\theta_{3\text{ dB}}$: The minimum 3 dB beamwidth of the receive antenna at each frequency of interest. $\theta_{3\text{ dB}}$ is the minimum of both the E-plane and H-plane values at each frequency. $\theta_{3\text{dB}}$ may be obtained from manufacturer-provided data for the receive antenna.
- d: The measurement distance (in meters). This is measured as the horizontal distance between the periphery of the EUT and the reference point of the receive antenna.
- w: The dimension of the line tangent to the EUT formed by $\theta_{3\text{ dB}}$ at the measurement distance d. Equation (9) shall be used to calculate w for each actual antenna and measurement distance used. The values of w shall be included in the test report. This calculation may be based on the manufacturer-provided receive-antenna beamwidth specifications:

$$w = 2d\tan\left(0{,}5\,\theta_{3\text{dB}}\right) \tag{9}$$

  w shall be of the minimum dimension as specified in Table 3.
- h: The height of the receive antenna, measured from its reference point to the floor.

Table 3 specifies the minimum acceptable dimension of w (w_{min}). The minimum requirements shown in Table 3 are calculated from Equation (9) based on testing at the minimum permitted measurement distance of 1 m specified in 7.6.2, and the values of $\theta_{3\ \text{dB(min)}}$ shown. The selection of measurement distance d and antenna type shall be made such that w is equal to or greater than the values shown in Table 3 at any frequency where the field is measured. At frequencies not shown in Table 3, the limit of w_{min} shall be linearly interpolated between the nearest two frequencies listed. Table 4 gives example values of w calculated using Equation (9) for three antenna types, at measurement distances of 1 m, 3 m, and 10 m.

The maximum emission is measured by moving the receive antenna in height along with rotation of the EUT in azimuth (0° to 360°). The required range of height investigation is specified below and illustrated in Figure 16 for two typical categories of EUTs.

Table 3 – Minimum dimension of w (w_{min})

Frequency GHz	$\theta_{3\ \text{dB, min}}$ °	w_{min} m
1,00	60	1,15
2,00	35	0,63
4,00	35	0,63
6,00	27	0,48
8,00	25	0,44
10,00	25	0,44
12,00	25	0,44
14,00	25	0,44
16,00	5	0,09
18,00	5	0,09

NOTE 1 The dimension, w, is permitted to be larger than the minimum shown, and other antennas and distances may be used to satisfy the minimum required value of $w = w_{\text{min}}$ shown, provided that Equation (9) is met.

NOTE 2 Because both polarizations are required to be measured for each height of the receive antenna, w forms a minimum square observation area equal to w^2 (m^2).

NOTE 3 In some cases, w may encompass multiple physical components of the EUT that are physically separated. For example, multiple separate cabinets of a multi-cabinet system that are tested simultaneously.

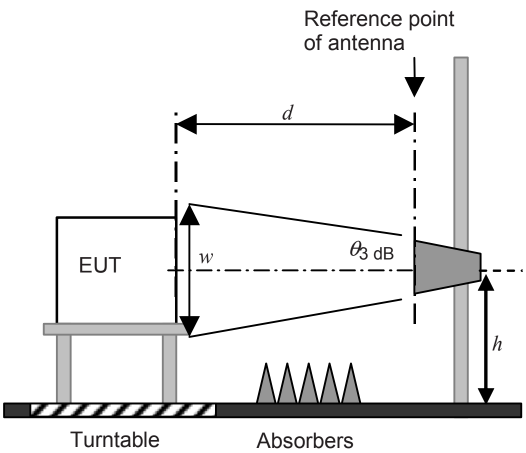
NOTE 4 The height scan requirement depends on w such that it may be advantageous to maximize w by selection of a wider beamwidth antenna and a larger measurement distance than the minimum requirements shown.

NOTE 5 The pattern and beamwidth of the antenna used can affect the measurement result. The antenna has at least two influence factors in addition to uncertainty in the antenna factor: 1) ripple or other anomalies in the antenna pattern, and 2) beamwidth differences between antennas, which may give different results depending on how many (constructive) emissions emanating from separate physical locations on the EUT fall within the antenna beamwidth.

Table 4 – Example values of *w* for three antenna types

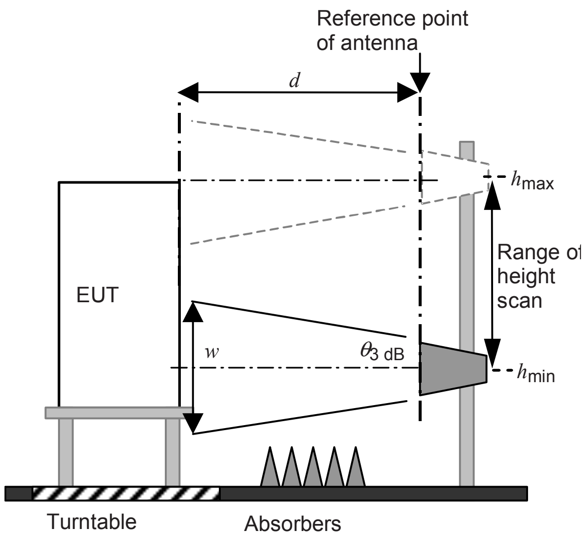
Frequency GHz	DRG Horn				LPDA or LPDA-V [a]			
	$\theta_{3\ dB}$ °	d = 1 m, w m	d = 3 m, w m	d = 10 m, w m	$\theta_{3\ dB}$ °	d = 1 m, w m	d = 3 m, w m	d = 10 m, w m
1,00	60	1,15	3,46	11,55	60	1,15	3,46	11,55
2,00	35	0,63	1,89	6,31	55	1,04	3,12	10,41
4,00	35	0,63	1,89	6,31	55	1,04	3,12	10,41
6,00	27	0,48	1,44	4,80	55	1,04	3,12	10,41
8,00	25	0,44	1,33	4,43	50	0,93	2,80	9,33
10,00	25	0,44	1,33	4,43	50	0,93	2,80	9,33
12,00	25	0,44	1,33	4,43	50	0,93	2,80	9,33
14,00	25	0,44	1,33	4,43	45	0,83	2,49	8,28
16,00	5	0,09	0,26	0,87	40	0,73	2,18	7,28
18,00	5	0,09	0,26	0,87	40	0,73	2,18	7,28

[a] LPDA-V: V-type log periodic dipole array. The values shown for $\theta_{3\ dB}$ and w are typical of both the LPDA and LPDA-V. However, these antennas typically have different gains.



a) w encompasses EUT height (fixed-height measurement)

IEC 767/10



b) w does not encompass EUT height (height scan required)

IEC 768/10

Figure 16 – Illustration of height scan requirements for two different categories of EUTs

For any EUT with maximum dimensions equal to or smaller than w, the centre of the receive antenna shall be fixed at the height of the centre of the EUT (Figure 16 a)). For any EUT with a maximum vertical dimension larger than w, the centre of the antenna shall be scanned vertically along the line parallel to w, as shown in Figure 16 b). The required scanning range for h is 1 m to 4 m. If EUT height is less than 4 m, scanning the centre of the receive antenna to heights above the top of the EUT is not required. In both cases the fixed height, h, or the range of heights investigated shall be recorded in the test report.

NOTE When a height scan is required per the above paragraph, a continuous height scan within the required height range is recommended, to obtain the final, maximum emission. If stepped height increments are used, caution is advised to ensure that the height increments are sufficiently small in order to capture the maximum emission.

Regarding the horizontal extent of *w*, the EUT is not required to be fully within *w*. In cases where the EUT width is larger than *w*, the EUT shall be centred horizontally on the measurement axis, and rotation of the EUT provides the necessary horizontal scan for the determination of the maximum field strength. Horizontal-line (sideways, transverse) scanning by moving the receive antenna horizontally off the measurement axis is not required, but may be used if specified in a product standard.

7.6.6.2 Measurements using conventional (non-statistical) detectors

7.6.6.2.1 General measurement procedure

[A1⟩For any EUT, the frequencies of emission should first be detected by a preliminary emission maximization procedure (see 7.6.6.2.2). Then the final emission test is performed (see 7.6.6.2.3). Both of these measurements are to be made preferably at the specific limit distance. If, for any justified reason, the final measurement is performed at a distance [A2⟩other than⟨A2] the limit distance, a measurement at the limit distance should be made first, to help in interpreting the resulting data.⟨A1]

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

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

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

[A2⟩ 7.6.6.2.2 Conditional testing procedure

If the highest internal frequency of the EUT (see 3.27) is less than 108 MHz, emissions shall be measured at least up to 1 GHz.

If the highest internal frequency of the EUT is between 108 MHz and 500 MHz, emissions shall be measured at least up to 2 GHz.

If the highest internal frequency of the EUT is between 500 MHz and 1 GHz, emissions shall be measured at least up to 5 GHz.

If the highest internal frequency of the EUT is above 1 GHz, emissions shall be measured up to the lower of 5 times the highest internal frequency or the highest frequency at which the limits are defined. ⟨A2]

A2 7.6.6.2.3 Preliminary measurement procedure

The procedures of this subclause are for informative purposes – normative measurement requirements are listed in 7.6.6.2.4. The maximum radiated disturbance for a given mode of operation may be found during a preliminary test. To minimize measurement time, it is suggested to first perform measurements using peak detection, and then compare the test results to the average limit. Subsequent measurements with the average detector and comparison of results to the average limit will only be performed in those frequency ranges where the average limit was exceeded by data collected with peak detection.

Guidelines for a preliminary procedure to identify the radiated disturbance are as follows.

a) Use scan or sweep mode over the complete frequency range of the antenna using peak detection and max-hold mode.
b) Determine the proper sweep or scan time to ensure adequate signal interception.
c) If necessary, during preliminary tests, reduce the resolution bandwidth in sweep mode to reduce the displayed noise level of the measuring receiver. Note that this may reduce the amplitude of broadband disturbance, so additional investigations to determine whether the disturbance is broadband or narrowband may be necessary.
d) Rotate the EUT continuously or in increments of 15 ° or less, then repeat for the other polarization. The EUT should be rotated 360 ° in azimuth for both polarizations to determine the maximum disturbance at each frequency of interest.
e) For continuous turntable rotation mode, set the measuring receiver sweep time such that the selected frequency span can be swept within a time that is equal to or less than the time needed for the turntable to rotate 15 °. If the rotational speed of the turntable is such that an angle larger than 15 ° is covered during a complete sweep or scan of the measuring receiver, a smaller frequency range should be used to reduce measuring receiver sweep time and to achieve the maximum 15 ° turntable rotation per sweep.
f) As needed to identify the frequencies corresponding to the maximum disturbance, apply the method described above for all the height levels required by 7.6.6.1 (and Figure 16), and for the various operating modes of the EUT.
g) To further evaluate the frequencies found in steps a) to d), use a small frequency span (typically 5 MHz or less) and investigate around frequencies near the limit using additional smaller turntable increments and height steps. Typically, all frequencies within approximately 10 dB of the specification limit warrant further investigation with a narrow frequency span and additional finer rotation/height increments.

7.6.6.2.4 Final measurement procedure

The field strength emitted by the EUT at the given measurement distance is measured using the configuration (antenna height, EUT azimuth, etc.) producing the maximum disturbance, as identified during the preliminary disturbance maximization. Final measurements shall be done using the EUT operational mode identified by preliminary measurements to have the highest disturbance.

This final measurement shall be the result of a maximum hold on the measuring receiver during a given time proportional to the frequency span used. This given time should be defined for each product or product family, taking into account the duration of the operating modes and the time constants associated with each specific product to be tested. Final measurements shall be performed using all required detectors. Alternatively, peak measurement results may be used to demonstrate compliance with all specified limits. A2

[A2⟩ If the configuration of the EUT (antenna height, EUT azimuth, operation mode, etc.) producing the maximum disturbance was not conclusively determined by a preliminary measurement the following additional measurements shall be done:

a) for any EUT with maximum dimension equal to or smaller than w, the centre of the receiving antenna shall be fixed at the height of the centre of the EUT [see Figure 16 a)];

b) for any EUT with maximum vertical dimension larger than w, height scanning shall be performed in accordance with the height scan requirements (upper and lower bounds) specified in 7.6.6.1;

c) in all cases, in order to find the maximum disturbance, the EUT shall be rotated in azimuth through all angles in the range of 0 ° to 360 °, and the measurements shall be performed for both horizontal and vertical polarizations.

In summary, the requirements for final measurements above 1 GHz are as follows.

The maximum disturbance shall be recorded from the following required investigations, some of which may be performed during the preliminary measurement procedure:

1) the EUT shall be rotated in azimuth through all angles in the range of 0 ° to 360 ° either by a turntable or movement of the receive antenna around the volume;

   NOTE If a preliminary measurement was performed with azimuth steps of 1 ° < a ≤ 15 °, the final measurement shall include an azimuth search continuous through all angles of at least ± a around the azimuth angle found in the preliminary measurement, where a is the azimuth angle.

2) the receive antenna shall be height-scanned if the EUT height is larger than w in the vertical direction;

3) both horizontal and vertical polarizations shall be investigated.⟨A2]

7.6.6.3 Measurements using APD (statistical) function

7.6.6.3.1 General

The measurement of the amplitude probability distribution (APD) of a disturbance signal provides a statistical characterization of the disturbance signal in question. [A2⟩ Background material on the application of the APD-measuring function is provided in 4.7 of CISPR/TR 16-3 [2]. ⟨A2]. A product committee may choose the APD measurement as the method to be used for final emission testing. The APD measurement shall be made at those frequencies where the EUT generates high disturbance field strengths. The number and selection method of frequencies shall be established by a product committee.

APD measurement shall be made using one of the following two methods. The first method is for measurement of the disturbance level E_{meas} in dB(µV/m) related to the specified probability of time p_{limit}, designated as Method 1 (see 7.6.6.3.2). The second method is the measurement of the probability of time p_{meas} during which the disturbance envelope exceeds a specified level E_{limit} in dB(µV/m), designated as Method 2 (see 7.6.6.3.3). Additional information and figures are given in Annex D to show the specifics of the two APD measurement methods.

If a product committee decides to use the APD approach, either Method 1 or Method 2 shall be selected. If the APD measuring instrument does not include an A/D converter, only Method 2 shall be used. If the APD measuring instrument includes an A/D converter, either Method 1 or Method 2 may be used.

The number of pairs of limits (E_{limit}, p_{limit}) and their values shall be specified by the product committee. The product committee shall also decide whether to also use a peak limit together with the APD limits.

7.6.6.3.2 Method 1 – Measurement of the level of disturbance

The measurement shall be performed using the following procedure:

1) Set the resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyzer according to CISPR 16-1-1 (for measurements above 1 GHz).
2) Find the frequencies at which high disturbances are observed. This can be accomplished by using the maximum hold function in the frequency span of interest. Peak detection shall be used when applying this procedure.

   NOTE In cases where narrowband emissions are hidden by broadband emissions, the maximum hold mode in combination with the peak detector may overlook narrowband emissions. Therefore, an additional measurement may be needed to find the frequencies of the narrowband emissions to be measured. The product committee may require additional sweeps using the average detector or digital video averaging. Furthermore, the number of frequencies for the APD measurement may also be specified by the product committee.
3) Determine the frequencies for the APD measurement. The number of the frequencies shall be specified by the product committee.
4) Set the centre frequency of spectrum analyzer to the frequency at which the highest level is observed during the application of step 2) of this procedure.
5) Set the reference level of the spectrum analyzer to minimum 5 dB above the maximum level of disturbance that is obtained in step 2).
6) Set the spectrum analyzer to the zero frequency span mode and measure the APD of disturbance during the measurement time that is specified by the product committee. The measurement time shall be longer than the period of the disturbance.

   In case of fluctuating disturbance frequencies, the product committee shall specify the frequency range XX (in MHz) in which the APDs of the disturbance shall be measured. APDs within the range XX MHz shall be measured with a 1 MHz frequency step size. However, for frequency ranges with APD measurement values that are greater than -6 dB from the APD limit, additional measurements may be needed with a smaller frequency step size (e.g. 0,5 MHz). The product committee shall define the smaller frequency step size.
7) Change the centre frequency of spectrum analyzer to the next frequency determined in step 2), then repeat the procedures of steps 4) to 6) until the APD measurements for all frequencies are carried out.
8) Read the disturbance level E_{meas} in dB(μV/m) related to the specified probability p_{limit} from the results of step 6).
9) Compare E_{meas} dB(μV/m) against the limit E_{limit} dB(μV/m). The EUT complies if E_{meas} is less than or equal to E_{limit} at all frequencies.

7.6.6.3.3 Method 2 – Measurement of the probability of time

The measurement shall be performed using the following procedure:

Steps 1), 2), 3), 4), 5) and 7) of Method 2 are the same as the corresponding steps of Method 1 (7.6.6.3.2).

For Method 2, modify step 6), step 8), and step 9) of Method 1 as follows:

6) Set the spectrum analyzer to the zero frequency span mode and measure the APD (or measure the probability p_{meas} related to the specified levels directly) of the disturbance during the measurement time that is to be specified by the product committee.
8) Read the probabilities p_{meas} during which the disturbance envelope exceeds a specified level E_{limit} in dB(μV/m) from the results of step 6).
9) Compare p_{meas} against the limits p_{limit}. The EUT complies if p_{meas} is less than or equal to p_{limit} at all frequencies.

7.6.7 Measurement uncertainty for FAR

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.7 *In situ* measurements (9 kHz to 18 GHz)

7.7.1 Applicability of and preparation for *in situ* measurements

In situ measurements may be necessary for the investigation of an interference problem at a particular location, i.e. where electrical equipment is suspected of causing interference to radio reception in its vicinity. Where allowed by the relevant product standard, *in situ* measurements may be made for the evaluation of compliance, if it is not possible for technical reasons to make radiated emission measurements on a standard test site. Technical reasons for *in situ* measurements are excessive size and/or weight of the EUT or situations where the interconnection to the infrastructure for the EUT is too expensive for the measurement on standard test sites. *In situ* measurement results of an EUT type will normally deviate from site-to-site or from results obtained on a standard test site and can therefore not be used for type testing.

NOTE 1 In general, however, due to imperfections such as mutual coupling between the conductive structures present in the *in situ* environment, which may also be more or less corrupted by ambient electromagnetic fields, and the measuring antenna/equipment under test, *in situ* measurements cannot fully replace measurements on a suitable test site [open-area test site or alternative test site, for example (semi-) anechoic chamber] as specified in CISPR 16-1-4.

The EUT usually consists of one or more devices and/or systems, is part of an installation, or is interconnected with an installation. A perimeter connecting the outer parts of the EUT is usually taken as the reference point to determine the measurement distance. In some product standards, the exterior walls or boundaries of business parks or industrial areas are taken as the reference points.

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

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

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

Measurements shall be made around the EUT at approximately the same measurement distance on each of the selected frequencies to determine the direction of the highest disturbance field strength. The EUT should be tested in at least three different directions. The final disturbance field-strength measurements on each frequency shall be made in the directions of the highest disturbance field strengths, which may vary from frequency to frequency, taking into account the local (ambient) conditions. The highest disturbance field strengths shall be measured with the antenna in vertical and horizontal polarization. If the ratio of the measured disturbance field strength to any ambient emission is lower than 6 dB, the measurement methods described in Annex A can be used.

7.7.2 Field-strength measurements *in situ* in the frequency range 9 kHz to 30 MHz

7.7.2.1 Measurement method

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

The horizontally-polarized disturbance field strength shall be measured at the standard measurement distance d_{limit} using a loop antenna as described in 4.3.2 of CISPR 16-1-4 at a height of 1 m (between the ground and lowest part of the antenna). The maximum disturbance field strength shall be determined by rotating the antenna.

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

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

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

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

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

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

7.7.2.2 Measurement distances other than the standard distance

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

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

7.7.3 Field-strength measurements *in situ* in the frequency range above 30 MHz

7.7.3.1 Measurement method

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

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

7.7.3.2 Measurement distances other than the standard distance

The standard measurement distance d_{std} is specified in the product or generic standard. If it is not possible to adhere to the standard measurement distance, the disturbance field strength shall be measured in different measuring distances as described in 7.7.2.2. A height scan of the antenna shall be used for each measurement The disturbance field strength at the standard distance d_{std} shall be determined according to 7.7.2.2 by plotting the measured field strength as a function of the measurement distance on a logarithmic scale.

If it is not possible to measure at varying distances, and the measurement distance refers to the outer wall of a building or the border of the premises, the measurement results shall be converted to the standard distance using Equation (10).

$$E_{\text{std}} = E_{\text{meas}} + 20\, n \log \frac{d_{\text{meas}}}{d_{\text{std}}} \qquad (10)$$

where

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

The factor n depends on the distance d_{meas} as follows:

if 30 m ≤ d_{meas}, n = 1;

if 10 m ≤ d_{meas} < 30 m, n = 0,8;

if 3 m ≤ d_{meas} < 10 m, n = 0,6.

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

Measurement distances closer than 3 m shall not be used.

If it is not possible to measure at varying distances, and Equation (10) is not used because the measurement distance does not refer to the outer wall of a building or boundary of premises, the field strength should be determined by measurement of the radiated disturbance power (see 7.7.4).

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

7.7.4.1 General measurement condition

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

If the EUT cannot be removed, and if its front face is a large plane surface, the effect of this face on the substitution shall be accounted for [see Equation (12)]. If the front surface of the EUT does not fit into a two-dimensional plane in the measurement direction, the additional measurement uncertainty is not considered.

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

7.7.4.2 Frequency range of 30 MHz to 1 000 MHz

7.7.4.2.1 Measurement distance

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

- d is greater than $\lambda/(2\pi)$ and
- $d \geq 2D^2/\lambda$ (11)

where

d is the measurement distance in m;
D is the maximum dimension of the EUT with cabling in m;
λ is the wavelength in m;

or if measurement distance d is equal to or greater than 30 m. In the far field, the exponent n in Equation (10) may be assumed to be one (1). If a shorter measurement distance is chosen, this assumption can be validated by using the procedure of 7.7.3.2 to verify that the field strength falls off inversely with distance. If the local conditions require that a shorter measurement distance be chosen, this shall be indicated.

7.7.4.2.2 Measurement method

The effective radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. The measurement distance shall be chosen according to 7.7.4.2.1 and the highest disturbance field strength on the selected frequency determined by varying the antenna height at least in the range of 1 m to 4 m as far as practicable.

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

a) The EUT shall be disconnected and removed. A half-wave dipole or antenna with similar radiation characteristics and known gain G, relative to a half-wave dipole is substituted in its place. If it is impractical to remove the EUT, a half-wave or broadband dipole (in the frequency range lower than about 150 MHz to minimize mutual coupling to the EUT) is positioned in the vicinity of the EUT. The vicinity is a range up to 3 m.
b) The half-wave (or broadband) dipole shall then be fed by a signal generator operating on the same frequency.
c) The position and polarization of the half-wave dipole (or broadband antenna) shall be such that the measuring receiver receives the highest field strength. If the EUT is not removed, then, if possible, it shall be switched off and the dipole is moved in a range up to 3 m around the EUT.
d) The power of the signal generated shall be varied until the measuring receiver shows the same reading as when the highest disturbance field strength from the EUT was measured.
e) If the EUT constitutes the front of a large plane surface (e.g. a building with a cable-TV network), the substitution antenna (half-wave dipole) is positioned about 1 m in front of the large plane surface (e.g. the front wall of a building). The location of the substitution measurement shall be selected such that an imaginary line between the substitution antenna and the measuring antenna is perpendicular to the direction of the face of the building.
f) The height, polarization and distance between the half-wave dipole (or broadband antenna) and the plane surface shall be varied such that the receiver displays the highest field-strength reading.
g) The power of the signal generator shall be varied as in d).

For removed EUTs, and EUTs that cannot be removed [see steps a) and c), respectively], the power at the signal generator, P_g, plus the gain of the transmit antenna relative to a half-wave dipole, G, yields the effective radiated disturbance power, P_r, to be measured:

$$P_r = P_g + G \tag{12}$$

For EUTs having a large plane surface (e.g. buildings with telecommunication networks), the increase in gain of the dipole positioned in front of this surface is given by:

$$P_r = P_g + G + 4 \text{ dB} \tag{13}$$

where

P_r is in dB(pW);

P_g is in dB(pW); and

G is in dB.

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

$$E_{\text{free}} = \frac{7\sqrt{P_{\text{r}}}}{d_{\text{std}}} \tag{14}$$

where

E_{free} is in µV/m;

P_{r} is in pW and

d_{std} is in m.

If the calculated free-space field strength of Equation (14) is compared with limits of disturbance field strength measured at a standard test site, it must be considered that the amplitude field strength measured at a standard test site is approximately 6 dB higher than the free-space field strength of Equation (14), due to the reflections from the ground plane. Equation (14) can be modified to take into account this difference. The disturbance field strength at the standard distance E_{std} can therefore be calculated, for the vertical polarization case, using the following equation:

$$E_{\text{std}} = P_{\text{r}} - 20\log d_{\text{std}} + 22{,}9 \tag{15}$$

For horizontal polarization below 160 MHz the maximum field strength is not measured at standard test sites. Therefore the 6 dB factor must be corrected using the following equation, for that Table 5 shows several calculated values:

$$E_{\text{std}} = P_{\text{r}} - 20\log d_{\text{std}} + 16{,}9 + (6 - c_{\text{c}}) \tag{16}$$

where

E_{std} is in dB(µV/m);

f is the measuring frequency;

d_{std} is in m; and

c_{c} is the correction factor for horizontal polarization. This was determined assuming a radiation source at 1 m in height.

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

Table 5 – Horizontal polarization correction factors as a function of frequency

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

7.7.4.3 Frequency range of 1 GHz to 18 GHz

7.7.4.3.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. The far-field condition shall be verified by measuring the radiated disturbance power with a double-ridged waveguide horn or log-periodic antenna as a function of distance. The requirement is met if the measurement distance is equal to, or greater than, the transition distance. The transition distance is marked by the transition point that shall be determined as shown in Figure 17. The measurement results shall be plotted and two parallel lines separated by 5 dB drawn to enclose as many of the measurement results; the transition point is the point where the lines intersect and after which the radiated power decreases by 20 dB/decade.

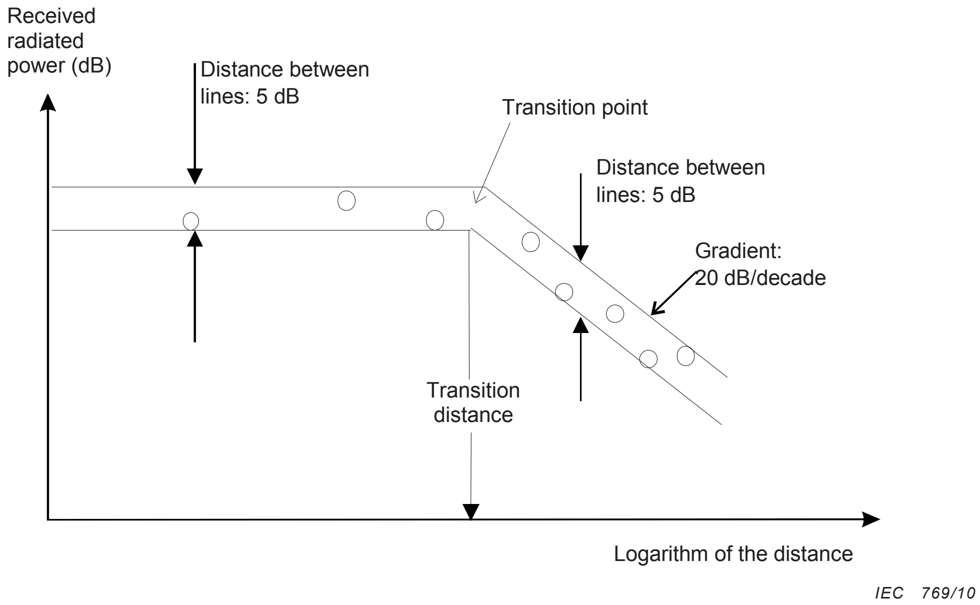


Figure 17 – Determination of the transition distance

7.7.4.3.2 Measurement method

The radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. A double-ridged waveguide horn or log-periodic antenna shall be used to determine the direction of maximum radiation. The measurement distance shall then be chosen according to 7.7.4.2.1 and the disturbance field strength on the selected frequency is measured. The antenna position shall be varied slightly to ensure that the measured field strength is not at a local minimum (for example, due to reflections).

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

$$P_r = P_g + G \qquad (17)$$

where

P_r is in dB(pW);

P_g is in dB(pW) and

G is in dB.

7.7.5 Documentation of the measurement results

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

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

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

7.7.6 Measurement uncertainty for *in situ* method

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.8 Substitution measurements (30 MHz to 18 GHz)

7.8.1 General

The substitution method is intended for measuring radio disturbance radiated from the cabinet, including wiring and circuitry inside the cabinet, of an equipment under test. The EUT may be either a self-contained unit with no port for any connection or have one or several ports for power and other external connections. For future product standards, product committees are invited to use the field-strength measurement method described in 7.6 for 1 GHz to 18 GHz.

7.8.2 Test site

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

Two horizontal half-wavelength dipoles, designated A and B (see also 7.8.3), shall be placed parallel to each other, at the same height h, with height not less than 1 m above the floor and spaced at the measurement distance d. Dipole B shall be connected to a signal generator and dipole A connected to the input of the measuring receiver. The signal generator shall be tuned to give maximum indication on the measuring receiver and its output adjusted to a convenient level. The site shall be considered suitable for the purpose of measurement at the test frequency if the indication on the measuring receiver does not vary more than ± 1,5 dB when dipole B is moved 100 mm in any direction. The test shall be repeated throughout the frequency range at frequency intervals small enough to ensure that the site is satisfactory for all measurements intended. If an EUT requires that measurements also be made with vertical polarization (see 7.8.4), the suitability test of the site shall be repeated with the two dipoles positioned for vertical polarization.

7.8.3 Test antennas

The test antennas A and B of Figure 18 have been described above as half-wave dipoles. For the frequency range below 1 GHz, this requirement applies primarily to the transmitting antenna B for which the radiated power in the direction of maximum radiation must be relatable to the power at the terminals of antenna B. The measuring antenna A should also be a half-wave dipole. Its actual sensitivity will be included in the substitution calibration of the test configuration. In the frequency range of 1 GHz to 18 GHz linearly-polarized horn antennas are recommended.

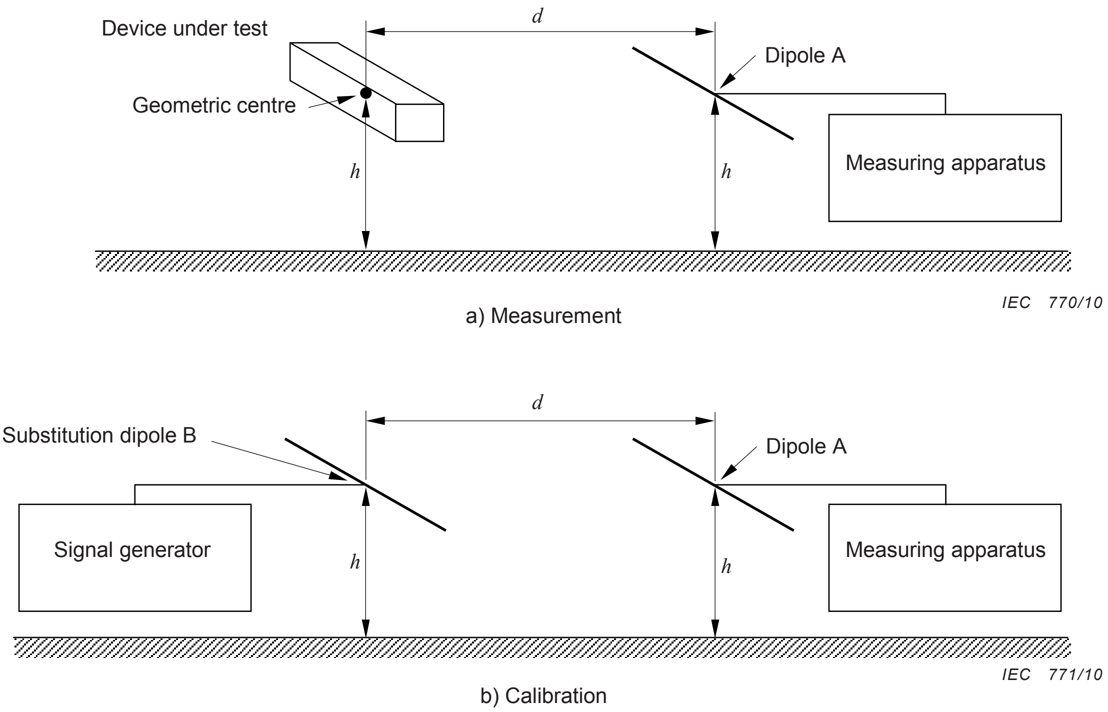


Figure 18 – Substitution method set-up geometries for: a) measurement, b) calibration

7.8.4 EUT configuration

The EUT shall be placed on a non-conducting table with provision to rotate in the horizontal plane (azimuth). The EUT shall be configured so that the geometric centre of the EUT coincides with the point earlier used as the centre point for dipole B (see Figure 18). If the EUT consists of more than one unit, each unit shall be measured separately. Detachable leads to the EUT should be removed if operation is not affected adversely. Required leads shall be provided with absorbing ferrite rings and be so positioned that they will not influence the measurements. For shielded EUTs, all connectors not used shall be terminated by shielded terminations.

7.8.5 Test procedure

With the EUT arranged as described in 7.8.4, the horizontally polarized measuring dipole A shall be placed in the same position as when checking the test site. The dipole shall be normal to a vertical plane through its centre and that of the EUT. The EUT is first measured in its normal table-standing position and secondly when tilted 90° to stand on a normally vertical side. In each position it shall be rotated 360° in the horizontal plane. The highest reading shall be the characteristic value for the EUT.

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

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

7.8.6 Measurement uncertainty for substitution method

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.9 Reverberation chamber measurements (80 MHz to 18 GHz)

Radiated emission measurements may be performed in reverberation chambers using the methods specified in IEC 61000-4-21. Conditions for the use of alternative test methods are given in CISPR 16-4-5. General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

7.10 TEM waveguide measurements (30 MHz to 18 GHz)

Radiated emission measurements may be performed in TEM waveguides using the methods specified in IEC 61000-4-20. Conditions for the use of alternative test methods are given in CISPR 16-4-5. General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

8 Automated measurement of emissions

8.1 Introduction – precautions for automated measurements

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

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

8.2 Generic measurement procedure

Signals need to be intercepted by the EMI receiver before they can be maximized and measured. The use of the quasi-peak detector during the emission maximization process for all frequencies in the spectrum of interest leads to excessive test times (see 6.6.2). Time-consuming processes like antenna height scans are not required for each emission frequency. These should be limited to frequencies at which the measured peak amplitude of the emission is above or near the emission limit. Therefore, only the emissions at critical frequencies whose amplitudes are close to or exceed the limit will be maximized and measured. The generic process depicted in Figure 19 will yield a reduction in measurement time.

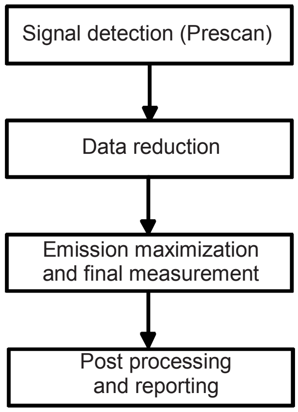


Figure 19 – Process to give reduction of measurement time

8.3 Pre-scan measurements

8.3.1 General

This initial step in the overall measurement procedure serves multiple purposes. Pre-scan places the least number of restrictions and requirements upon the test system since its main purpose is to gather a minimal amount of information upon which the parameters of additional testing or scanning will be based. This measurement mode can be used to test a new product, where the familiarity with its emission spectrum is very low. In general, pre-scan is a data acquisition procedure used to determine where in the frequency range of interest, significant signals are located. Depending on the goal of this measurement, antenna tower and turntable movement may be necessary (for the radiated emission test) as well as improved frequency accuracy (e.g. for further processing on an OATS) and data reduction through amplitude comparison. These factors define the measurement sequence during the execution of pre-scan. In any case, the results will be stored in a signal list for further processing. When a pre-scan measurement is made to quickly obtain information on the unknown emission spectrum of an EUT, frequency scanning can be performed by applying the considerations of 6.6.

8.3.2 Determination of the required measurement time

If the emission spectrum and especially the maximum pulse repetition interval T_p of the EUT are not known, they shall be investigated to assure the measurement time T_m is not shorter than T_p. The intermittent character of the emission of an EUT is especially relevant for critical peaks of the emission spectrum. First it should be determined at which frequencies the amplitude of the emission is not steady. This can be done by comparing the max-hold with a min-hold or clear/write function of the measuring equipment or software, and observing the emission for a period of 15 s. During this period no change in the set-up should be made (no change of lead in case of conducted emission, no movement of absorbing clamp, no movement of turntable or antenna in case of radiated emission). Signals with e.g. more than

2 dB difference between the max-hold result and min-hold result are marked as intermittent signals. (Care should be taken not to mark noise as intermittent signals.)

In case of radiated emission, the polarization of the antenna is changed and the measurement is repeated, to reduce the risk that certain intermittent peaks are not found because they remain below noise level. From each intermittent signal the pulse repetition period T_p can be measured, by applying zero-span or using an oscilloscope connected to the IF-output of the measurement receiver. The correct measurement time can also be determined by increasing it until the difference between max-hold and clear/write displays is below e.g. 2 dB. During further measurements (maximization and final measurement), it shall be assured for each part of the frequency range that the measuring time T_m is not smaller than the applicable pulse repetition period T_p.

8.3.3 Pre-scan requirements for different types of measurements

The type of measurement determines the definition of a pre-scan measurement in the following way:

- For radiated emissions in the frequency range from 9 kHz to 30 MHz, e.g. per CISPR 11, both the loop antenna and the EUT need to be rotated to find the maximum field strength while the receiver is scanning the emission spectrum.
- In the frequency range from 30 MHz to 1 000 MHz, the antenna height may be preset to fixed heights given in Table 6, based on measurement distance, frequency range and polarization. The necessary pre-scan measurements must be made for a sufficient number of EUT azimuths. For quick overview measurements this will yield an indication of the radiated emission amplitudes as a starting point for final maximization. If a more detailed determination of the worst-case antenna height, polarization and EUT azimuth is desired, the applicable standard should be used to determine the appropriate maximization procedure.
- In the frequency range above 1 GHz, the antenna needs to be positioned in horizontal and vertical polarization and the EUT rotated to find the maximum field strength while the emission spectrum is scanned. For details of the test procedure, see 7.6.6.1.

Table 6 – Recommended antenna heights to guarantee signal interception (for pre-scan) in the frequency range 30 MHz to 1 000 MHz

Measurement distance m	Polarization h - horizontal v - vertical	Frequency range MHz	Recommended antenna heights for each frequency range (minimum / maximum) m
3	h	30 to 100	2,5
		100 to 250	1 / 2
		250 to 1 000	1 / 1,5
	v	30 to 100	1
		100 to 250	1 / 2
		250 to 1 000	1 / 1,5 / 2
10	h	30 to 100	4
		100 to 200	2,5 / 4
		200 to 400	1,5 / 2,5 /4
		400 to 1 000	1 /1,5 /2,5
	v	30 to 200	1
		200 to 300	1 / 3,5
		300 to 600	1 / 2 / 3,5
		600 to 1 000	1 / 1,5 / 2 / 3,5
30	h	30 to 300	4
		300 to 500	2,5 / 4
		500 to 1 000	1,5 / 2,5 / 4
	v	30 to 500	1
		500 to 800	1 / 3,5
		800 to 1 000	1 / 2,5 / 3,5

NOTE 1 The recommended antenna heights were derived for source phase-centre heights of between 0,8 m and 2,0 m for maximum errors of 3 dB (which is good for a pre-scan only). If the range of phase centre heights is reduced, the number of receive antenna heights may be reduced. If radiation pattern lobes exist (distinct peaks and nulls), e.g. in the upper frequency ranges, more antenna heights may be needed.

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

8.4 Data reduction

The second step in the overall measurement procedure is used to reduce the number of signals collected during pre-scan and is thus aimed at further reduction of the overall measurement time. These processes can accomplish various tasks, e.g. determination of significant signals in the spectrum, discrimination between ambient or auxiliary equipment signals and EUT emissions, comparison of signals to limit lines, and data reduction based on user-definable rules. Another example of data-reduction methods involving the sequential use of different detectors and amplitude versus limit comparisons is given by the decision tree in Annex C of CISPR 16-2-1. Data reduction may be performed fully automated or interactively, involving software tools or manual operator interaction. It need not be a separate section of the automated test, i.e. it may be part of a pre-scan.

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

8.5 Emission maximization and final measurement

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

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

- In the frequency range from 9 kHz to 30 MHz – maximization of the indicated level by variation of the EUT azimuth angle and the and the azimuth angle of the (vertical) plane of the loop antenna (e.g. tests for CISPR 11);
- In the frequency range from 30 MHz to 1 000 MHz – maximization of the indicated level by variation of height and polarization of the measurement antenna as well as variation of the EUT azimuth;
- In the frequency range above 1 GHz – maximization of the indicated level by variation of the antenna polarization and variation of the EUT azimuth and, if the EUT surface is wider than the antenna beam, by moving the antenna along the EUT surface.

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

The measurement of a particular radiated emission includes a maximization process involving the rotation of the EUT, scanning the receive antenna over a height range, and changing antenna polarization. This time-consuming search process can be effectively automated, but it must be recognized that a variety of search strategies may be used that can lead to different results. In case of previous knowledge of the radiation characteristics of an EUT, a maximization sequence should be chosen that allows the determination of the worst-case amplitude within the search ranges of the antenna mast and the turntable. For instance, if the EUT emits highly directive signals in the horizontal plane, e.g. due to slots in the case, the turntable should be rotated continuously while taking data with the receiver. A table movement in discrete steps, on the other hand, may not allow the detection of the maximum amplitude or may cause the signal to be missed completely if the chosen angular increments of the positions are too far apart. The scan time of the spectrum analyzer should be less than the time for 15º of rotation of the turntable to produce effective maximization data.

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

A1 NOTE The final measurement may be performed at several frequencies in parallel using FFT-based measurement instrumentation. A1

8.6 Post-processing and reporting

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

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

A1 8.7 Emission measurement strategies with FFT-based measuring instruments

Depending on the implementation, FFT-based measuring instruments may perform weighted measurements significantly faster than the tunable selective voltmeters. A weighted measurement over the frequency range of interest may then be faster than a measurement consisting of a prescan and final scan performed with a superheterodyne receiver as described in 8.2. A1

Annex A
(informative)

Measurement of disturbances in the presence of ambient emissions

A.1 General

High ambient emissions have to be accounted for during *in situ* tests (conducted and radiated) and type tests on an open-area test site (OATS). It is the purpose of this annex to describe measurement procedures for a number of different situations.

In some circumstances, the procedures will not provide a solution to the problems caused by ambient signals. In particular, the procedures cannot be expected to overcome the problems of 5.2.4 of CISPR 16-1-4. But aside from this caveat, the following procedures can be used.

A.2 Definitions

A.2.1
EUT disturbance
EUT emission spectrum to be measured

A.2.2
ambient emission
emission spectrum superimposed on the EUT disturbance spectrum that influences the accuracy of the EUT disturbance measurement

[A2) *Text deleted* (A2]

A.3 Problem description

During *in situ* tests and type tests on an OATS the ambient emissions frequently do not correspond to the ambient radio frequency environment of the test site recommendations of CISPR 16-1-4.

The radio disturbance of the EUT is often located within the frequency bands of ambient emissions and cannot be measured with a radio disturbance measuring receiver as specified in CISPR 16-1-1 due to insufficient frequency spacing between the EUT disturbance and the ambient emission or due to superposition.

The CISPR standard measuring receiver is suitable to provide uniform test results for all types of radio-frequency emissions, where the EUT disturbance alone is to be measured. It is, however, not optimized to discriminate between EUT disturbance and ambient emissions or to measure the EUT disturbance in the aforementioned situation.

Because in actual interference investigation situations there are no alternatives to an *in situ* test, a solution is described below for cases when a differentiation between EUT disturbance and ambient emission is possible.

A.4 Proposed solution

A.4.1 Overview

EUT disturbance emissions and ambient emissions can be categorized as in Table A.1.

Table A.1 – Combinations of EUT disturbance and ambient emissions

EUT disturbance	Ambient emission
Narrowband	Narrowband
	Broadband
Broadband	Narrowband
	Broadband

Narrowband ambient emissions may be, for example, AM- or FM-modulated; broadband ambient emissions may be, for example, TV or digitally-modulated signals. Here the terms "narrowband" and "broadband" are always relative to the bandwidth of the measuring receiver, as specified in CISPR 16-1-1. Narrowband signals are defined as signals that have a bandwidth less than the measuring receiver bandwidth. In this case, all the signal's spectral components are contained in the receiver bandwidth. A CW signal will always be narrowband; a narrow FM signal can be either narrow or broadband, depending on the actual receiver bandwidth. On the contrary, an impulsive signal will usually be broadband because a few of its spectral components will be within and many of its spectral components outside the receiver bandwidth.

The measurement of the EUT disturbance is a manifold problem: first, to identify EUT disturbance and ambient emission and, second, to distinguish between narrowband and broadband emission. Modern measuring receivers and spectrum analysers provide various resolution bandwidths and detector types. These can be used to analyse the combined spectrum, to distinguish between EUT disturbance and ambient emission spectra, to distinguish between narrowband and broadband emissions and to measure (or in difficult situations to estimate) the EUT disturbance.

In case of type testing on an OATS, identification and pre-measurement of the EUT disturbance may also be carried out by pre-testing the EUT in a non-compliant (for example, partially) absorber-lined shielded room, and final testing on an OATS, whereby levels of emissions hidden by ambients may be determined by comparison with emissions in the vicinity.

Superposition of the emissions shall be accounted for when EUT disturbance and ambient emissions cannot be separated. The separation needs a EUT disturbance-and-ambient-emission to ambient-emission ratio of about 20 dB.

In cases where IF-bandwidths and detectors are different from the specified bandwidth and the quasi-peak (QP) detector, the QP value in the specified bandwidth is the reference for the measurement-error determination.

Figure A.1 shows a flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection.

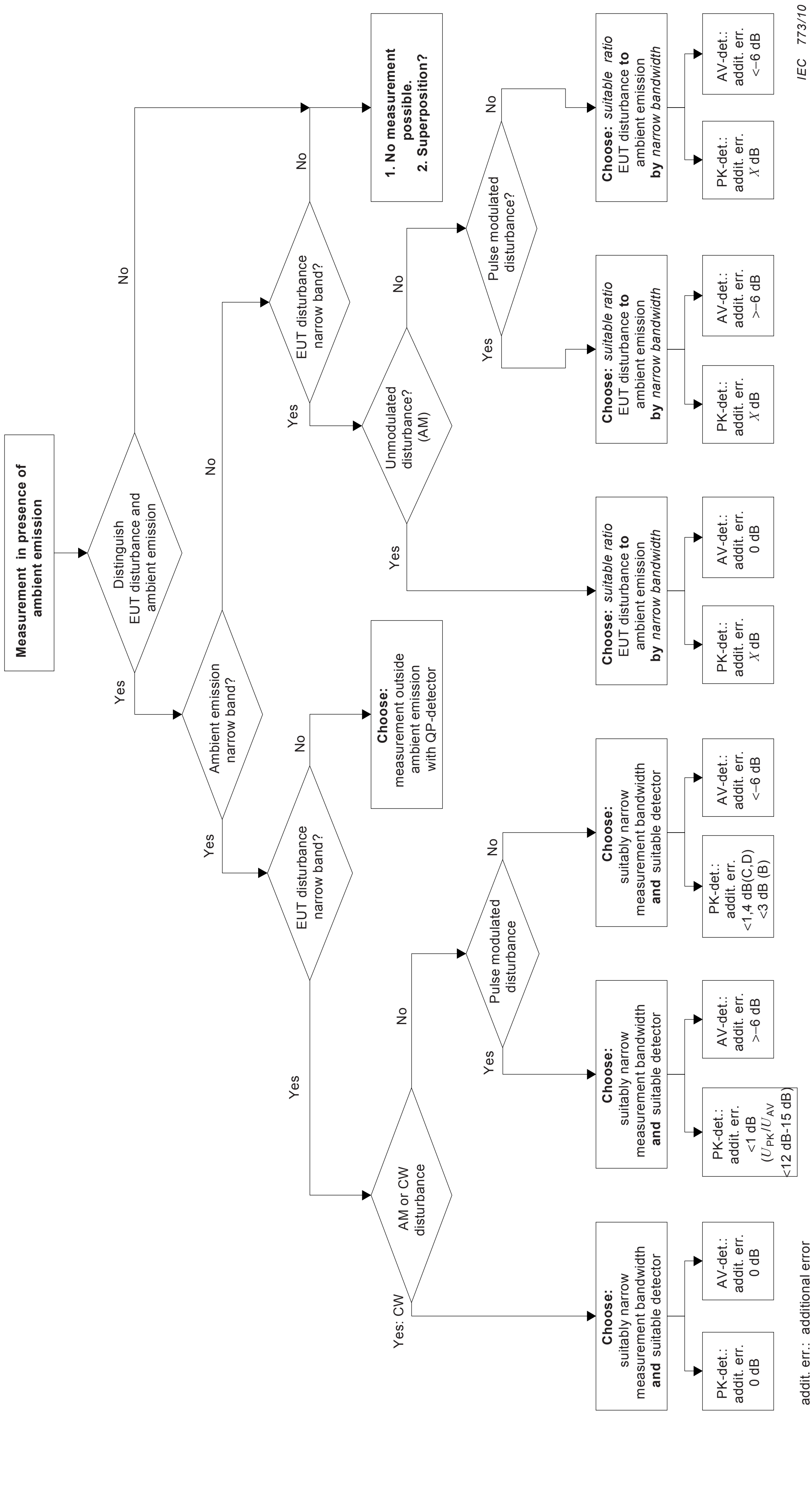


Figure A.1 – Flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection

A.4.2 Pre-testing the EUT in a shielded room

Emission frequency and amplitude data acquired from preliminary testing in a shielded room may be used under certain restrictive conditions [a simple shielded room is not an absorber-lined shielded room – semi-anechoic or anechoic – and thus does not meet present NSA values in Annex E of CISPR 16-1-4, (Annex A of [3])]. This will give the emission spectrum that has significant amplitudes. In cases of narrowband emission the product emission spectrum contains harmonics and subharmonics of any clock frequency used in the product.

These pre-test results may be used to determine product emission amplitudes in certain restrictive situations. In particular, when the final compliance test is performed at an OATS and one (or more) of the frequencies are masked (hidden) by an RF ambient, chances are that an adjacent frequency to these masked frequencies will not coincide precisely with an RF ambient. Hence, the unmasked emission can be recorded in the usual manner using the required receiver or spectrum analyser bandwidth. Then the amplitude of the EUT emission that is masked by the high RF ambient can be judged using the preliminary quiet-chamber measurements in the following way.

Assume that during the shielded room preliminary measurements that two adjacent frequency emissions are X dB different in amplitude (see Figure A.2). Next one of these frequencies that are not masked by the RF ambient is measured at the OATS. The difference in amplitude (X dB) of the masked frequency from the measurable adjacent frequency can be added to (or subtracted from, depending on the sign of the difference) the amplitude found in the shielded room to determine the amplitude of the adjacent frequencies. This is shown in Figure A.2, where (assuming that the frequency f_1 is the masked frequency and f_0 is not masked), the amplitude for f_1 is shown as X dB greater than the amplitude at f_0. Then to find the amplitude of f_1 at the OATS, X dB is added to the value of the measurable amplitude of f_0. Similarly, if the amplitude of f_6 were Y dB less than that for f_7 found during the quiet-chamber testing, the amplitude of f_6 (if masked by an ambient) would be Y dB less than that of f_7, which is assumed to be measurable at the OATS.

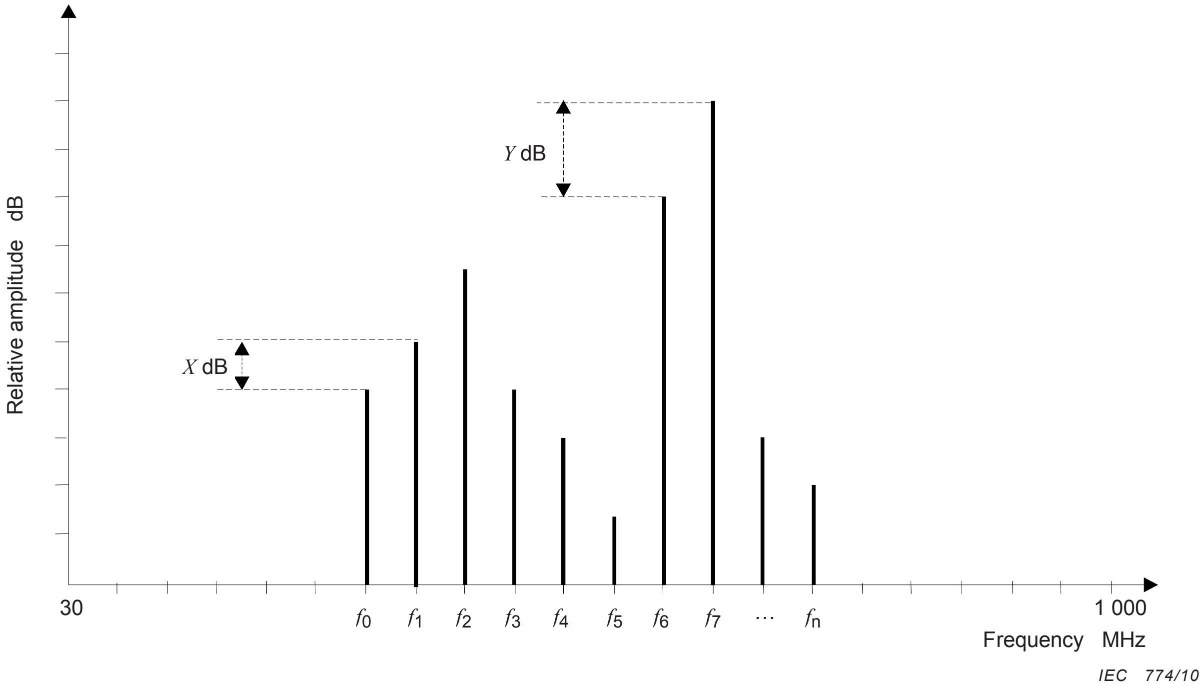
NOTE The above procedure emphasizes what is contained in point [A2] d [A2]) of 7.3.6.2 (Test environment).

Several precautions should be taken in using this restricted procedure.

a) The adjacent frequency found in preliminary testing should not be more than one or two adjacent frequencies away (usually a sub-harmonic or harmonic of the basic clock frequency), so that the effect of the shielded room irregularities will not unnecessarily enhance or depress frequencies adjacent to the frequency to be estimated on the OATS. In this case, the value of X (or Y in Figure A.2) may not be suitable.

b) The amplitudes of adjacent frequencies need to be measured very carefully by height scan of the receive antenna in the quiet chamber (as would be the case for the final compliance measurement). If full height scan cannot be made, alternate correlations between the quiet-chamber measurements and the corresponding OATS measurements may have to be made before applying this OATS amplitude estimation technique (for emissions masked by the RF ambient).

c) For those quiet chambers that are fully absorber-lined on all six sides of the chamber, alternate height-scan techniques might be available, such as measurements at two or three fixed heights (since the ground plane reflections are suppressed and that contribution to the received signal diminished) and using the maximum of these readings. Such techniques may need the same correlation measurements as stated in item b) above.



NOTE Generally f_n is n times f_0, the EUT fundamental emission frequency (basic clock frequency).

Figure A.2 – Relative difference in adjacent emission amplitudes during preliminary testing

A.4.3 Method of measurement of EUT disturbances in the presence of narrowband ambient emissions

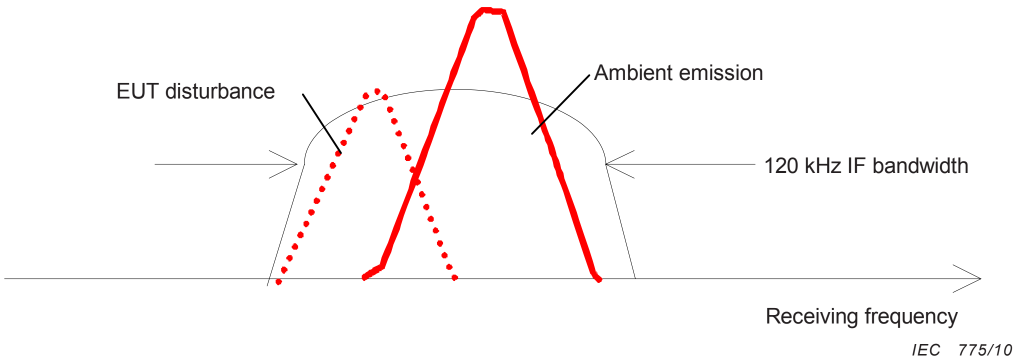
A.4.3.1 General

Depending on the type of EUT disturbance, its measurement is based on:

- the analysis of the combined spectrum with a bandwidth narrower than that of the CISPR measuring receiver;
- the determination of a suitable measurement bandwidth for the selection of narrowband disturbance close to ambient emissions;
- the use of the peak detector (if the disturbance is AM or pulse modulated) or the average detector;
- the increase of the EUT disturbance to ambient emission ratio in case of a narrowband disturbance within a relatively broadband ambient emission when a narrower measurement bandwidth is used; and
- accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

A.4.3.2 Unmodulated EUT disturbance

The unmodulated EUT disturbance (see Figure A.3) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Either the peak or the average detector may be used. There is no additional measurement error compared with the quasi-peak detector. If the difference in level between peak and average values is very small (for example, lower than 1 dB), the measured average value is equivalent to the quasi-peak value.



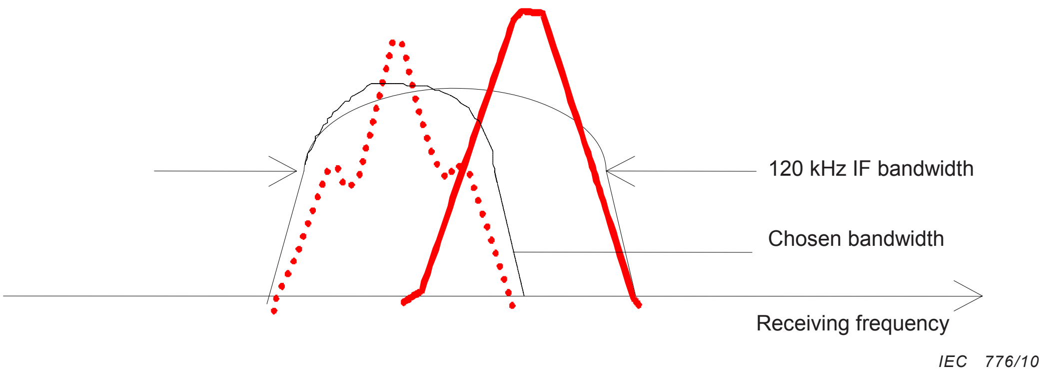
Key

dotted line	EUT disturbance
solid bold line	ambient emission
thin line	120 kHz IF bandwidth

Figure A.3 – Disturbance by an unmodulated signal (dotted line)

A.4.3.3 Amplitude-modulated EUT disturbance

The amplitude-modulated EUT disturbance (see Figure A.4) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Care should be taken to ensure that the narrow measurement bandwidth chosen does not suppress the modulation spectra of the EUT disturbance. Suppression of the modulation spectra is recognised by a decrease in the peak amplitude of the EUT disturbance as a result of the increase of selectivity.



Key

dotted line	EUT disturbance
solid bold line	ambient emission
thin line	120 kHz IF bandwidth

Figure A.4 – Disturbance by an amplitude-modulated signal (dotted line)

Only the peak detector with a measurement time greater than the reciprocal of the modulation frequency can be used. An additional measurement error shall be accounted for at modulation frequencies below 10 Hz (0,4 dB at 10 Hz; 1,4 dB at 2 Hz for bands C and D and 0,9 dB at 10 Hz; 3 dB at 2 Hz for band B), where the peak value is above the quasi-peak value. The QP-value as a function of the modulation frequency is shown in Figure A.5.

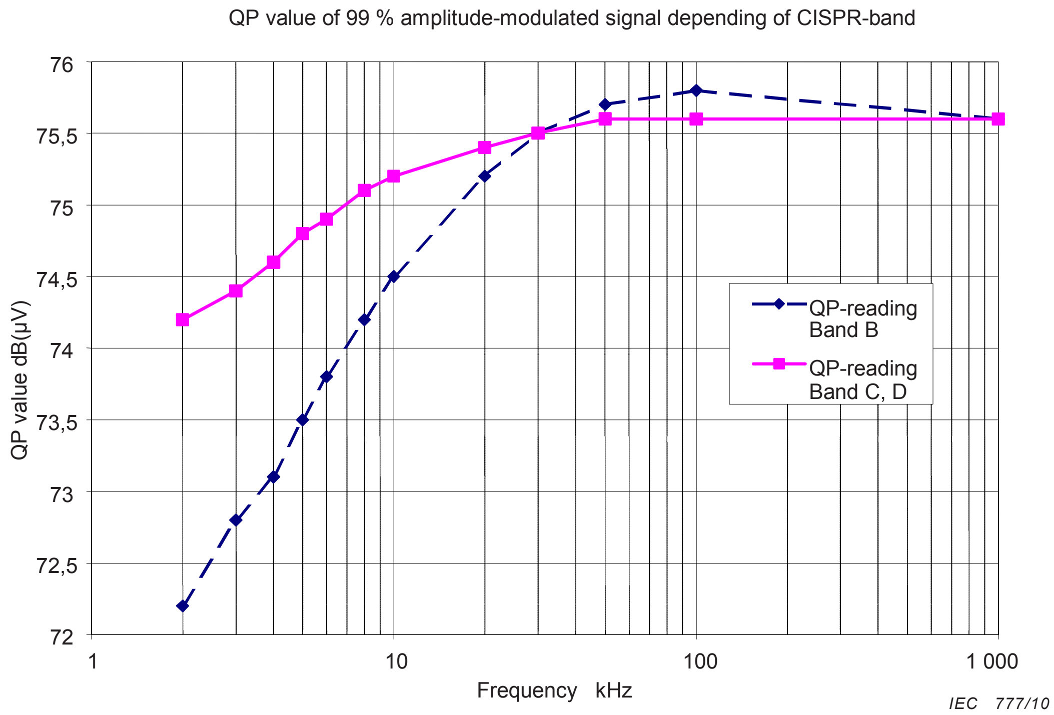


Figure A.5 – Indication of an amplitude-modulated signal as a function of modulation frequency with the QP detector in CISPR bands B, C and D

A.4.3.4 Pulse-modulated EUT disturbance

The narrowband pulse-modulated disturbance from the EUT is classified as a special case of amplitude modulation and can also be separated from the ambient signal carrier by a suitably narrow measurement bandwidth. The selectivity must not lead to a suppression of the modulation spectra. Only the peak detector can be used.

In cases of low repetition frequency, an additional error is possible, but as long as the difference between peak- and average detector reading is in the order of 12 dB to 14 dB, additional measurement errors compared with the quasi-peak value need not be accounted for.

For a pulse width t = 50 µs, Figure A.6 shows that as long as the difference between peak and average levels is less than or equal to 14 dB, the deviation between peak and QP levels is negligible. So, the comparison between peak and average levels may be used to verify the usability of the peak detector.

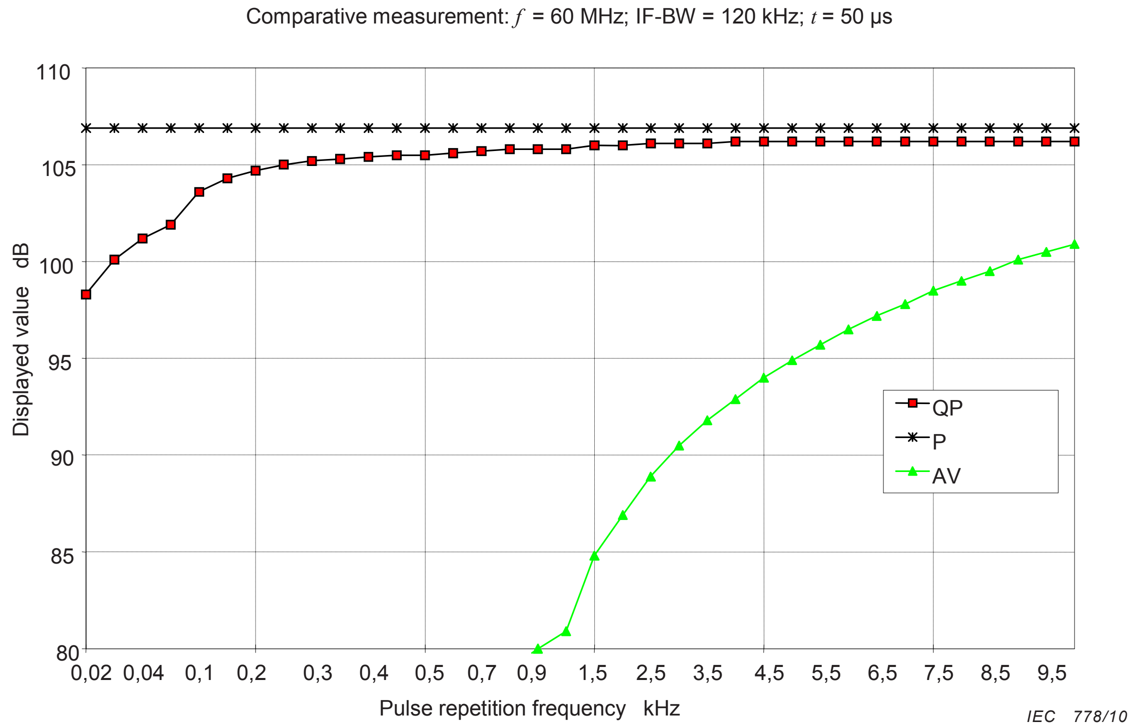
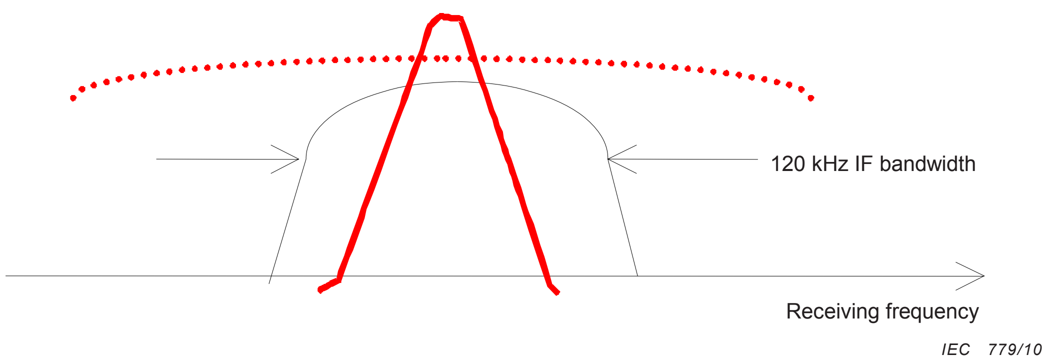


Figure A.6 – Indication of a pulse-modulated signal (pulse width 50 µs) as a function of pulse repetition frequency with peak, QP and average detectors

A.4.3.5 Broadband EUT disturbance

For the measurement of broadband disturbance (see Figure A.7) the quasi-peak detector shall be used. In fact it is not possible to carry out a measurement within the ambient signal bandwidth. Because of the finite bandwidth, the disturbance can generally be measured outside the ambient signal spectrum using the quasi-peak detector.



Key

dotted line	EUT disturbance
solid bold line	ambient emission
thin line	120 kHz IF bandwidth

Figure A.7 – Disturbance by a broadband signal (dotted line)

A.4.4 Method of measurement of EUT disturbance in the presence of broadband ambient emissions

A.4.4.1 General

For this case the measurement method is based on:

– the analysis of the combined spectrum with a bandwidth equal to the CISPR measuring receiver;

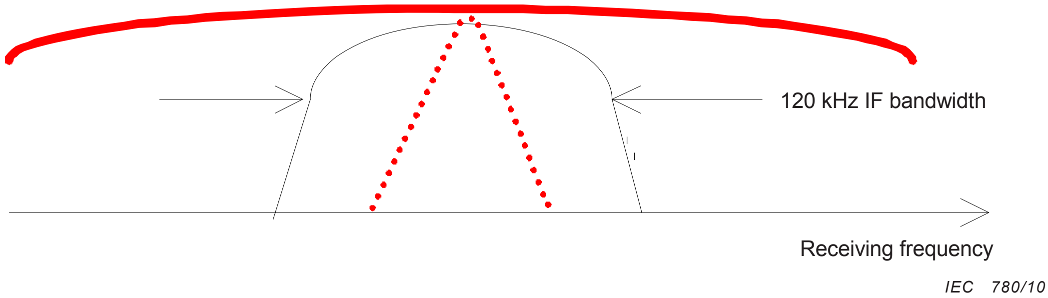
– measurement with a narrow bandwidth (in case of narrowband EUT disturbance; the use of a narrow bandwidth will increase the EUT disturbance to ambient emission ratio);

– the use of the average detector for narrowband EUT disturbance; and

– accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

A.4.4.2 Unmodulated EUT disturbance

The amplitude of the EUT disturbance (see Figure A.8) should be measured with the average detector (specified in CISPR 16-1-1). The measurement error depends on the average value of the broadband signal spectrum within the selected bandwidth. This measurement error can be minimized by choosing a measurement bandwidth that maximizes the EUT disturbance to ambient emission ratio (selectivity method).



Key

dotted line EUT disturbance

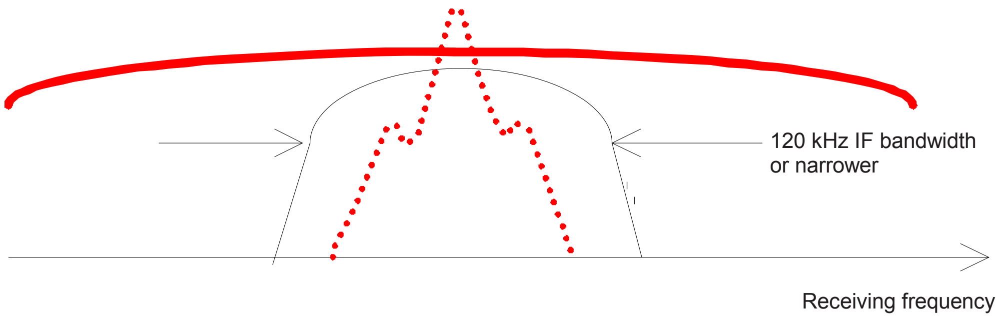
solid bold line ambient emission

thin line 120 kHz IF bandwidth

Figure A.8 – Unmodulated EUT disturbance (dotted line)

A.4.4.3 Amplitude-modulated EUT disturbance

The amplitude of the EUT disturbance (see Figure A.9) is measured with the average detector, although an additional measurement error of up to 6 dB (at 100 % modulation) compared with a quasi-peak detector shall be accounted for. The measurement bandwidths chosen should maximize the EUT disturbance to ambient emission ratio (selectivity method).



Key

dotted line	EUT disturbance
solid bold line	ambient emission
thin line	120 kHz IF bandwidth

Figure A.9 – Amplitude-modulated EUT disturbance (dotted line)

A.4.4.4 Pulse-modulated EUT disturbance

It is not easy to detect and recognise a pulse-modulated EUT disturbance in a broadband ambient signal spectrum with a high level of reliability, because the 100 % amplitude modulation of the disturbance may mask the EUT disturbance within the spectrum.

The amplitude of the EUT disturbance can be measured with the average detector in case of high duty cycles. Due to the 100 % amplitude modulation depth with smaller duty cycles, the use of the average detector will cause an increasing measurement error compared with the quasi-peak detector. In the case of a duty cycle of 1:1 and use of the linear average detector, the measurement error is 6 dB. The measurement bandwidth should be such that the relationship between the measured average value of the EUT disturbance and the average value of the broadband ambient signal is maximized.

In case of low duty cycles, the average value will substantially deviate from the QP value. In this case the peak detector should be used together with a measurement bandwidth as narrow as possible but still wide enough to capture the complete disturbance bandwidth. Superposition with the ambient emission may have to be accounted for.

A.4.4.5 Broadband EUT disturbance

As a rule, broadband disturbance cannot be detected or measured in a broadband ambient signal spectrum; it may be possible to measure such a disturbance outside the ambient signal spectrum or by accounting for superposition.

The combinations of EUT disturbance with the ambient emission, and the error involved in the measurement, are displayed in Table A.2.

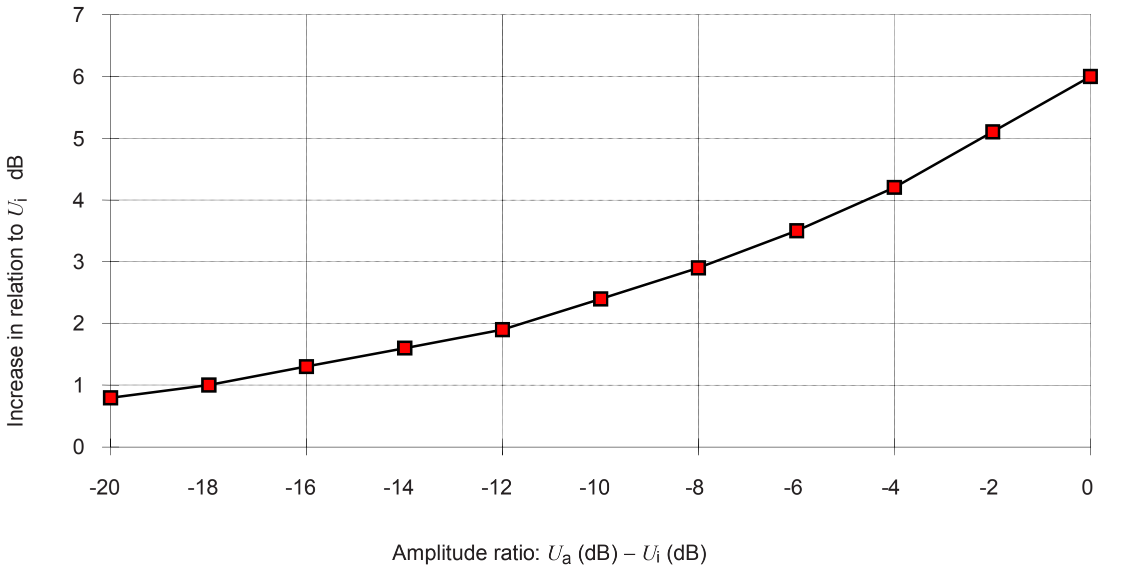
NOTE A scanning receiver or spectrum analyser will show the spectra of two different broadband signals, unless the signal frequencies or pulse rates are harmonically related with each other, or the sweep rate of the measuring instrument is harmonically related with the measured pulse rates.

A.5 Determination of the EUT disturbance in case of superposition

If, as a result of the selection of the EUT disturbance and the ambient emission, the measured level to ambient emission ratio is lower than 20 dB, the superposition of ambient emission and

EUT disturbance needs to be accounted for. For impulsive broadband voltage, the following calculation can be made.

The received signal U_r is the sum of the EUT disturbance U_i and the ambient emission U_a. U_a can be measured only when the EUT is switched off. The superposition is linear for the peak detector (Figure A.10).



U_a is level of ambient emission

U_i is level of EUT disturbance

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Figure A.10 – Increase of peak value with superposition of two unmodulated signals

The following equation applies when using the peak detector:

$$U_r = U_i + U_a \tag{A.1}$$

The EUT disturbance can thus be calculated from

$$U_i = U_r - U_a \tag{A.2}$$

The amplitude ratio d of the received signal to the ambient emission can be measured easily.

$$D = \frac{U_r}{U_a}, \qquad d = 20 \log D \tag{A.3}$$

The ambient emission U_a can be substituted in Equation (A.2):

$$U_i = U_r - \frac{U_r}{D} = U_r \left(1 - \frac{1}{D} \right) \tag{A.4}$$

or

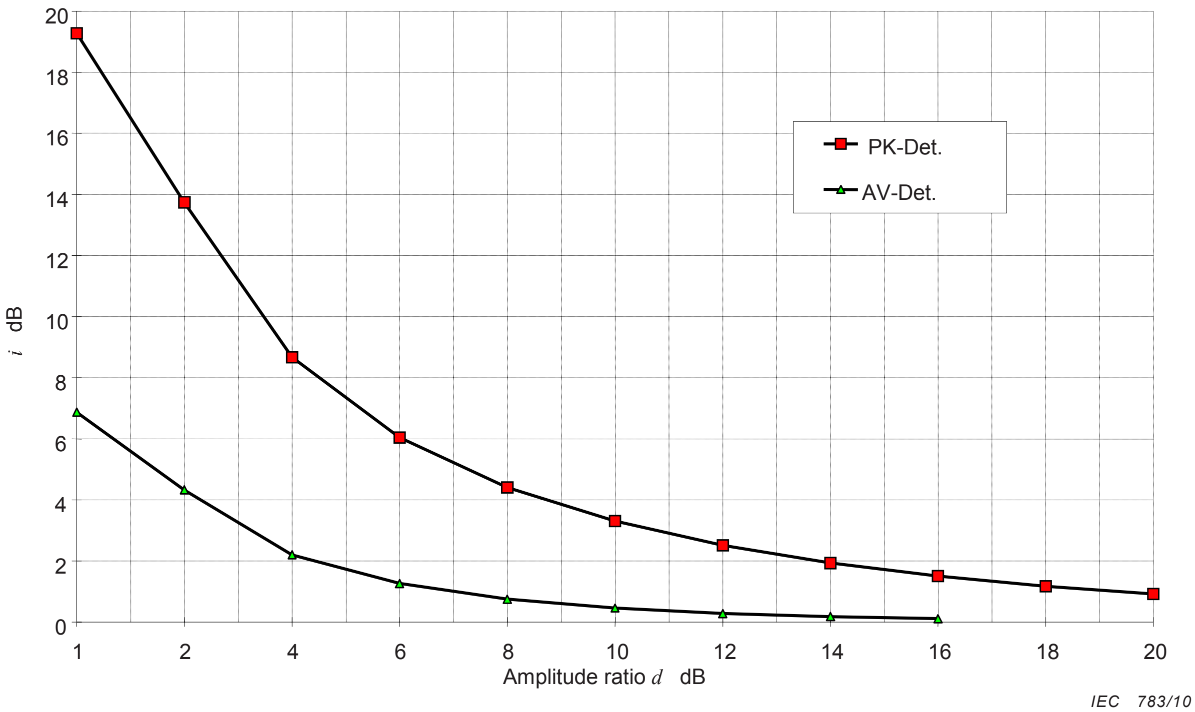
$$U_{\mathrm{i,dB}} = U_{\mathrm{r,dB}} + 20\log\left(1 - \frac{1}{D}\right) \quad \text{(A.5)}$$

Defining i by Equation (A.6) as

$$i = -20\log\left(1 - \frac{1}{D}\right) \quad \text{(A.6)}$$

serves to determine the amplitude of the EUT disturbance. The factor i is illustrated in Figure A.11. Using i from Figure A.11, the amplitude of the EUT disturbance can be calculated as follows:

$$U_{\mathrm{i,dB}} = U_{\mathrm{r,dB}} - i \quad \text{(A.7)}$$



U_a is the ambient signal in dB

U_r is the resulting indication of received signal (by superposition) in dB

U_i is the disturbance signal in dB

$d = U_r - U_a$

$U_i = U_r - i$

$i = -20\log(1 - 1/D)$

Figure A.11 – Determination of the amplitude of the disturbance signal by means of the amplitude ratio *d* and the factor *i* [see Equation (A.3) and Equation (A.6)]

Figure A.11 can be used as follows:

a) measure the ambient field strength U_a in dB(µV/m) (EUT off);

b) measure the resultant field strength U_r in dB(µV/m) (EUT on);

c) determine $d = U_r - U_a$;

d) find the value of i from Figure A.11;

e) determine U_i in dB(µV/m) using $U_i = U_r - i$.

If the received signal is measured with the average detector, Figure A.12 can be applied. Figure A.12 shows that in the case of unmodulated signals the following equation

$$U_r = \sqrt{U_i^2 + U_a^2} \tag{A.8}$$

can be used with an additional measurement error of up to about 1,5 dB. In case of modulation, the error decreases (see Figure A.12) but the errors in Table A.2 shall be accounted for.

By means of the average detector, the in-band disturbance can be estimated by applying Equation (A.7) if the curve of the average detector (Figure A.11) is used. In this case the factor i is defined as

$$i = -10\log\left(1 - \frac{1}{D^2}\right) \tag{A.9}$$

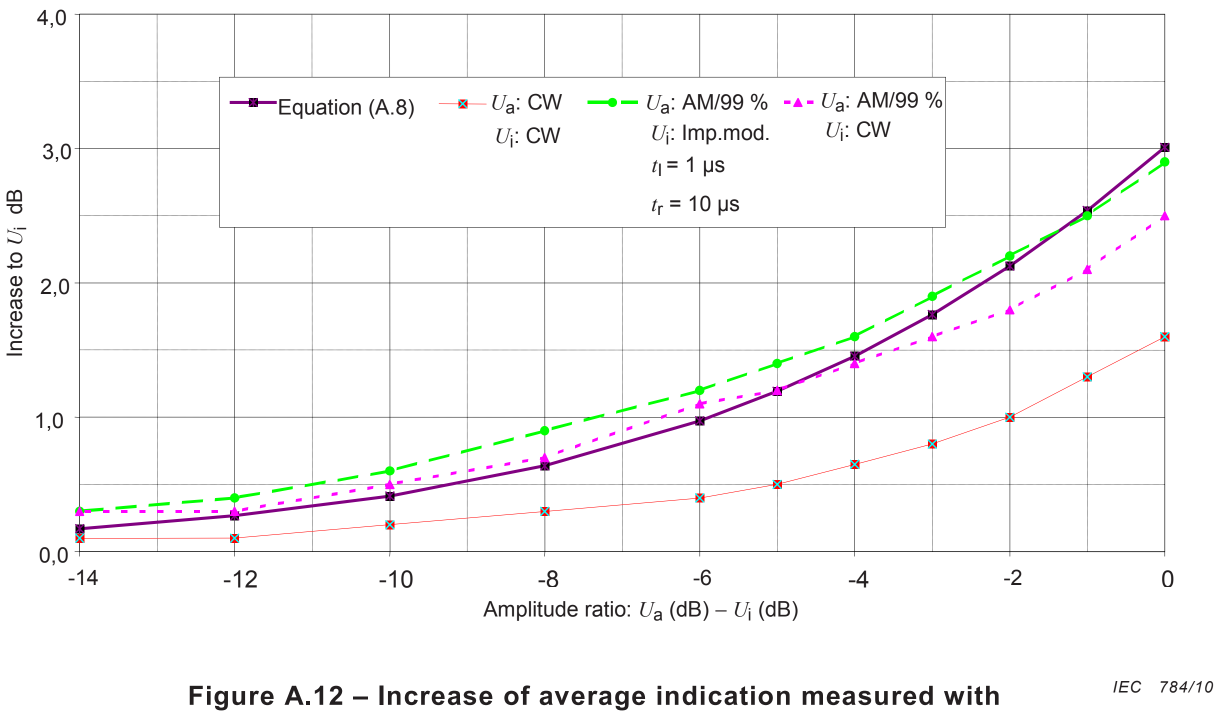


Figure A.12 – Increase of average indication measured with a real receiver and calculated from Equation (A.8)

Table A.2 – Measurement error depending on the detector type and on the combination of ambient and disturbing signal spectra

Ambient emission	EUT disturbance			
	Unmodulated	**Amplitude-modulated**	**Pulse-modulated**	**Broadband disturbance**
Narrowband				
Steps taken to increase signal-to-noise ratio	Increased selectivity	Increased selectivity	Increased selectivity	Measurement outside ambient emission
Error of peak value $\left(\frac{PK}{QP}\right)$	0 dB	Less than or equal to +1,4 dB for bands C, D +3 dB for band B	Less than or equal to +1 dB $\left(\frac{U_{PK}}{U_{AV}} \leq 12...15\ \text{dB}\right)$	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–
Broadband				
Steps taken to increase signal-to-noise ratio	Selectivity	Selectivity	Selectivity	No measurement possible (superposition only)
Error of peak value $\left(\frac{PK}{QP}\right)$	+X dB [a]	Less than or equal to +X dB [a]	Greater than or equal to +X dB [a]	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–

[a] Measurement procedure not recommended – not allowed for compliance measurements.

NOTE 1 X is the error depending on the pulse character of the ambient emission.

NOTE 2 PK is the peak value; QP is the quasi-peak value; AV is the average value.

NOTE 3 Bands B, C, D are defined as in CISPR 16-1-1

Annex B
(informative)

Use of spectrum analyzers and scanning receivers

B.1 General

When using spectrum analyzers and scanning receivers, the following characteristics should be addressed. See also Clause 6 of this standard for additional information.

B.2 Overload

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

B.3 Linearity test

Linearity can be evaluated by measuring the level of the specific signal under investigation and repeating this measurement after an X dB attenuator has been inserted at the input of the receiver or, if used, the preamplifier ($X \geq$ 6 dB). The new reading of the receiver display should differ by X dB up to ± 0,5 dB from the first reading, if the measuring system is linear.

B.4 Selectivity

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

B.5 Normal response to pulses

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

B.6 Peak detection

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

B.7 Frequency scan rate

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

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

For a spectrum analyzer or scanning receiver used in a fixed tuned non-scanning mode, the display sweep time may be adjusted independently of the detection mode and according to the needs for observing the behaviour of the emission. If the level of disturbance is not steady, the reading on the receiver must be observed for at least 15 s to determine the maximum (see 6.5.1).

B.8 Signal interception

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

B.9 Average detection

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

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

B.10 Sensitivity

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

The sensitivity to extremely broadband emissions that require large RF attenuation for system linearity is increased with RF preselecting filters ahead of the spectrum analyzer. The filters reduce the peak amplitude of the broadband emissions and less RF attenuation can be used.

Such filters may also be necessary to reject or attenuate strong out-of-band signals and the intermodulation products they cause. If such filters are used, they must be calibrated with broadband signals.

B.11 Amplitude accuracy

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

Annex C
(informative)

Scan rates and measurement times for use with the average detector

C.1 Purpose

This annex is intended to give guidance on the selection of scan rates and measurement times when measuring impulsive disturbance with the average detector.

The average detector serves the following purposes:

a) to suppress impulsive noise and thus to enhance the measurement of CW components in disturbance signals to be measured
b) to suppress amplitude modulation (AM) in order to measure the carrier level of amplitude modulated signals
c) to show the weighted peak reading for intermittent, unsteady or drifting narrowband disturbances using a standardized meter time constant.

Clause 6 of this standard defines the average measuring receiver for the frequency range 9 kHz to 1 GHz.

In order to select the proper video bandwidth and the corresponding scan rate or measurement time, the following considerations apply.

C.2 Suppression of disturbances

C.2.1 Suppression of impulsive disturbance

The pulse duration T_p of an impulsive disturbance is often determined by the IF bandwidth, B_{res}, i.e. $T_p = 1/B_{res}$. For the suppression of such noise, the suppression factor a is then determined by the video bandwidth B_{video} relative to the IF bandwidth, i.e. $a = 20\log(B_{res}/B_{video})$. The bandwidth B_{video} is determined by the bandwidth of the low-pass filter following the envelope detector. For longer pulses, the suppression factor will be lower than a. The minimum scan time $T_{s\,min}$ (and maximum scan rate $R_{s\,max}$) is determined using:

$$T_{s\,min} = \frac{k\,\Delta f}{B_{res}\,B_{video}} \tag{C.1}$$

$$R_{s\,max} = \frac{\Delta f}{T_{s\,min}} = \frac{B_{res}\,B_{video}}{k} \tag{C.2}$$

where

Δf is the frequency span and

k is a proportionality factor that depends on the speed of the measuring receiver or spectrum analyzer.

For the longer scan times, k is very close to a factor of one (1). If a video bandwidth of 100 Hz is selected, the maximum scan rates and pulse suppression factors in Table C.1 are obtained.

Table C.1 – Pulse suppression factors and scan rates for a 100 Hz video bandwidth

	Band A	Band B	Bands C and D
Frequency range	9 kHz to 150 kHz	150 kHz to 30 MHz	30 MHz to 1 000 MHz
IF bandwidth B_{res}	200 Hz	9 kHz	120 kHz
Video bandwidth B_{video}	100 Hz	100 Hz	100 Hz
Maximum scan rate	17,4 kHz/s	0,9 MHz/s	12 MHz/s
Maximum suppression factor	6 dB	39 dB	61,5 dB

This can be applied for product standards calling out quasi-peak and average limits in bands B (and C) if short pulses are expected in the disturbance signal. Compliance of the EUT with both limits shall be demonstrated. If the pulse repetition frequency is greater than 100 Hz and the quasi-peak limit is not exceeded by the impulsive disturbance, then the short pulses are sufficiently suppressed for average detection with a video bandwidth of 100 Hz.

C.2.2 Suppression of impulsive disturbance by digital averaging

Average detection may be done by digital averaging of the signal amplitude. An equivalent suppression effect can be achieved if the averaging time is equal to the inverse of the video filter bandwidth. In this case, the suppression factor a = 20 log($T_{av}B_{res}$), where T_{av} is the averaging (or measuring) time at a certain frequency. Consequently a measurement time of 10 ms will produce the same suppression factor as a video bandwidth of 100 Hz. Digital averaging has the advantage of zero delay time, when switching from one frequency to another. On the other hand, for averaging of a certain pulse repetition frequency f_p, the result may vary depending on whether n or (n+1) pulses are averaged. This has an effect of less than 1 dB, for $(T_{av}f_p) > 10$.

C.2.3 Suppression of amplitude modulation

In order to measure the carrier of a modulated signal, the modulation has to be suppressed by signal averaging over a sufficiently long time, or by using a video filter of sufficient attenuation at the lowest frequency. If f_m is the lowest modulation frequency, and assuming that the maximum measurement error due to a 100 % modulation is limited to 1 dB, then the measurement time T_m should be $T_m = 10/f_m$.

C.3 Measurement of slowly intermittent, unsteady or drifting narrowband disturbances

In CISPR 16-1-1, the response to intermittent, unsteady or drifting narrowband disturbances is defined using the peak reading with meter time constants of 160 ms (for Bands A and B) and 100 ms (for Bands C and D). These time constants correspond to 2^{nd}-order video filter bandwidths of 0,64 Hz or 1 Hz respectively. For correct measurements, these bandwidths would require very long measurement times (see Table C.2).

Table C.2 – Meter time constants and the corresponding video bandwidths and maximum scan rates

	Band A	Band B	Bands C and D
Frequency range	9 kHz to 150 kHz	150 kHz to 30 MHz	30 MHz to 1 000 MHz
IF bandwidth B_{res}	200 Hz	9 kHz	120 kHz
Meter time constant	160 ms	160 ms	100 ms
Video bandwidth B_{video}	0,64 Hz	0,64 Hz	1 Hz
Maximum scan rate	8,9 s/kHz	172 s/MHz	8,3 s/MHz

This applies, however, only for pulse repetition frequencies of 5 Hz or less. For all higher pulse widths and modulation frequencies, higher video filter bandwidths may be used (see C.2.1). Figure C.1 and Figure C.2 show the weighting function of a pulse with 10 ms pulse duration versus pulse repetition frequency f_p with peak reading (CISPR AV) and with true averaging (AV) for meter time constants of 160 ms (Figure C.1) and 100 ms (Figure C.2).

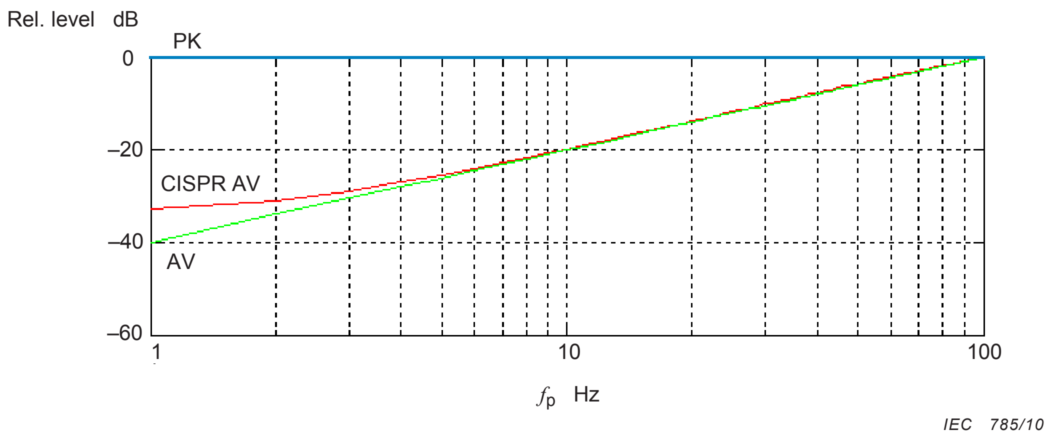


Figure C.1 – Weighting function of a 10 ms pulse for peak (PK) and average detections with (CISPR AV) and without (AV) peak reading: meter time constant 160 ms

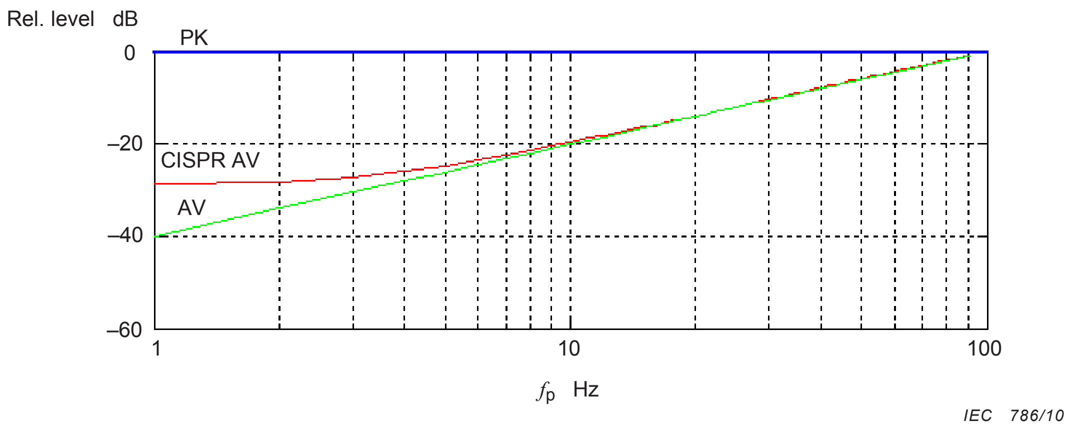


Figure C.2 – Weighting functions of a 10 ms pulse for peak (PK) and average detections with (CISPR AV) and without (AV) peak reading: meter time constant 100 ms

Figure C.1 and Figure C.2 imply that the difference between average with peak reading (CISPR AV) and without peak reading (AV) increases as the pulse repetition frequency f_p decreases. Figure C.3 and Figure C.4 show the difference for f_p = 1 Hz, as a function of pulse width.

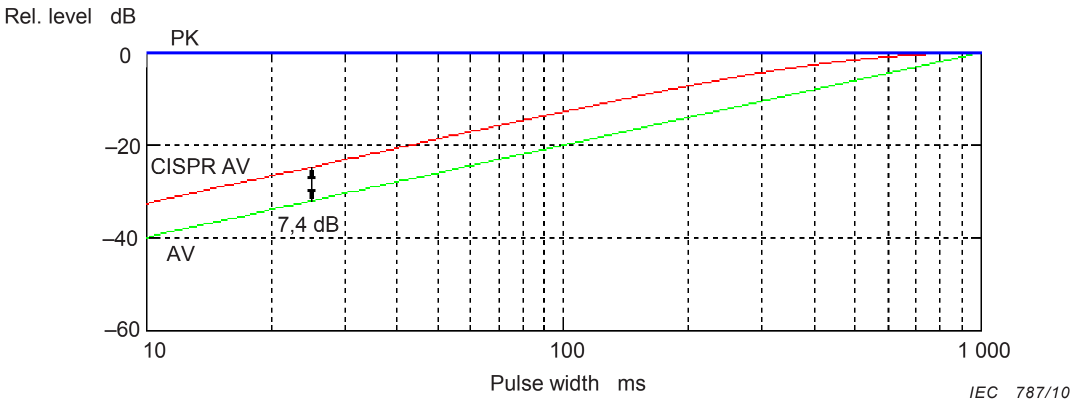


Figure C.3 – Example of weighting functions (of a 1 Hz pulse) for peak (PK) and average detections as a function of pulse width: meter time constant 160 ms

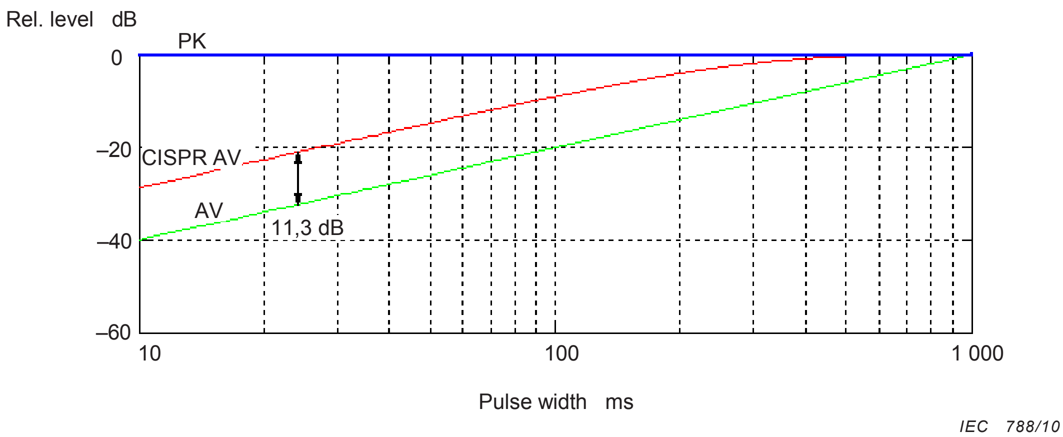


Figure C.4 – Example of weighting functions (of a 1 Hz pulse) for peak (PK) and average detections as a function of pulse width: meter time constant 100 ms

C.4 Recommended procedure for automated or semi-automated measurements

When measuring EUTs that do not emit slowly intermittent, unsteady or drifting narrowband disturbances, it is recommended to measure with the average detector using a video filter bandwidth of e.g. 100 Hz, i.e. a short averaging time during a pre-scan procedure. At frequencies where the emission is found to be close to the average limit, it is recommended to make a final measurement using a lower video filter bandwidth, i.e. a longer averaging time. (For the pre-scan/final measurement procedure, see also Clause 8 of this standard).

For slowly intermittent, unsteady or drifting narrowband disturbances, manual measurements are the preferred method.

Annex D
(informative)

Explanation of APD measurement method applying to the compliance test

One of the following two methods is used when the APD measurement is applied for a compliance test. Figure D.1 and Figure D.2 illustrate the specifics of the APD measurement methods, involving the measurement of the level of disturbance (i.e. Method 1, see 7.6.6.3.2) and the measurement of the probability (i.e. Method 2, see 7.6.6.3.3), respectively.

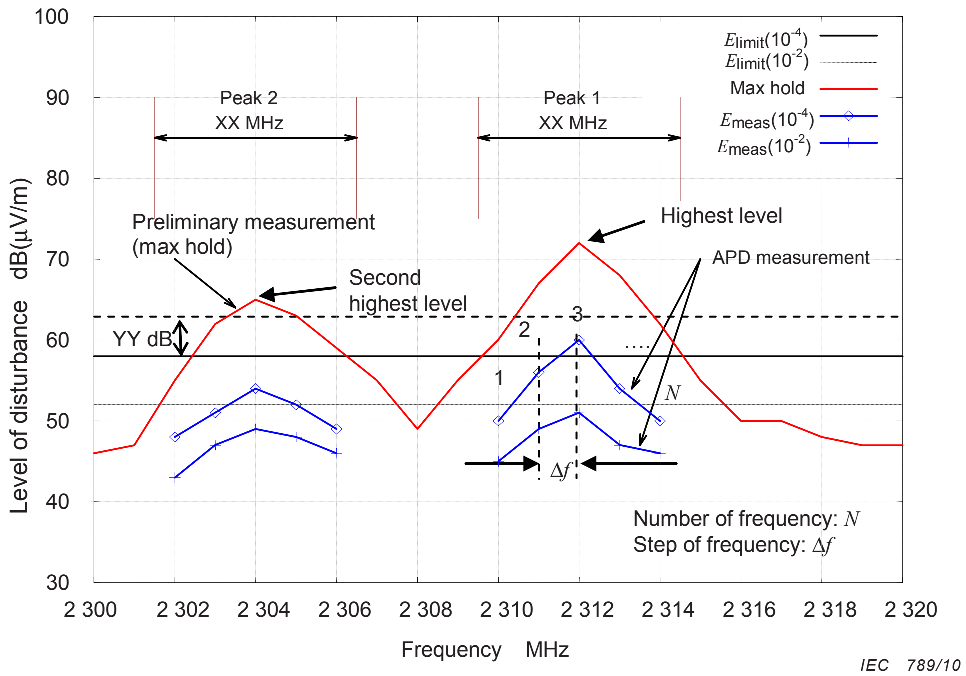


Figure D.1 – Example of APD measurement Method 1 for fluctuating disturbances

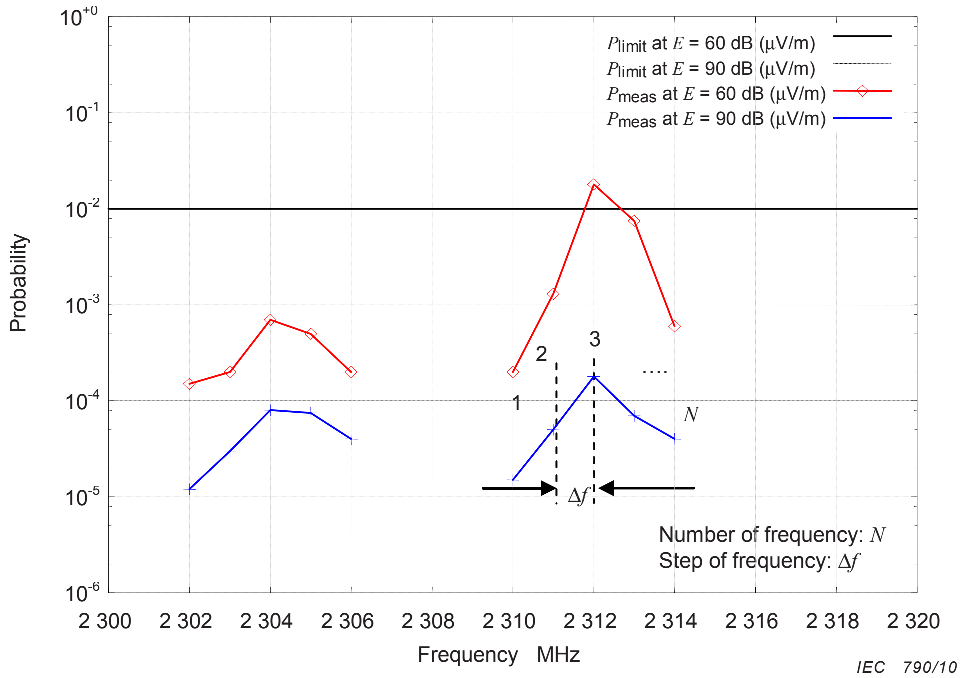


Figure D.2 – Example of APD measurement Method 2 for fluctuating disturbances

If the preliminary measurement results, obtained by using the maximum-hold display mode and peak detection, exceed the specified APD limit (the higher limit should be used if two APD limits apply) by YY dB at certain frequencies, then the APD measurement should be performed at these identified frequencies. The value YY dB is to be specified by the relevant product committee (e.g. YY = 5, 10, etc.).

In case of fluctuating disturbances, the product committee should specify the frequency range XX (= $\Delta f \times N$) MHz in which the APD measurements are to be performed, where Δf is the frequency step size and N is the number of frequencies. This frequency range should be specified according to the characteristics of the product.

As a first step, XX is determined by the preliminary measurement results. Then, Δf should be equal to the resolution bandwidth (RBW = 1 MHz for measurements above 1 GHz) of the spectrum analyzer. However, all frequencies that have an APD value within approximately 6 dB of the APD limit may require further investigation with a smaller frequency step size (i.e. $B_6/2$, where B_6 is the 6-dB bandwidth of the spectrum analyzer). RBW of the spectrum analyzer for measurements above 1 GHz is defined by the impulse bandwidth B_{imp} rather than the 6-dB bandwidth B_6. The relation between B_{imp} and B_6 is dependent upon the filter type, and cannot be generalized. If B_{imp} can be approximated to B_6, then the smaller frequency step size $B_6/2$ is recommended to be $B_{imp}/2$ (i.e. 0,5 MHz) for measurements above 1 GHz. Finally, N is determined from the values of XX and Δf.

Annex E
(normative)

Determination of suitability of spectrum analyzers for compliance tests

The user of a spectrum analyzer shall be able to demonstrate – either through specifications from the manufacturer or by measurement - that the analyzer meets the quasi-peak detection requirements for pulse-repetition frequencies greater than 20 Hz in the frequency range of use. For the average detector the response to pulses is called out in CISPR 16-1-1.

Since the measurement of the pulse repetition frequency of an emission may not always be possible, a simple method to verify the validity of the quasi-peak measurement shall be applied when a spectrum analyzer is used. This method is based on a comparison of measurement results with the peak and quasi-peak detectors. From the quasi-peak weighting functions, the amplitude differences shown in Table E.1 are the results of measurements for a signal with a pulse repetition frequency of 20 Hz.

Table E.1 – Maximum amplitude difference between peak and quasi-peak detected signals

Band A	Band B	Bands C and D
7 dB	13 dB	21 dB

The comparison measurement is to be made at signal frequencies that show amplitudes close to the applicable limit in quasi-peak detection. If the difference between the peak and quasi-peak detected amplitude is smaller than the value in Table E.1 the quasi-peak measurement is valid and the result obtained with a spectrum analyzer can be used to demonstrate compliance. If the amplitude difference is larger than the stated values in Table E.1 a measuring receiver that fully complies with the low-prf requirements of CISPR 16-1-1 is to be used for the quasi-peak measurement instead of a spectrum analyzer. This comparison measurement requires an adequate signal-to-noise ratio to ensure proper results.

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