NSAI Standards

Irish Standard
I.S. EN 55011:2016

Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

I.S. EN 55011:2016

Incorporating amendments/corrigenda/National Annexes issued since publication:

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Údarás um Chaighdeáin Náisiúnta na hÉireann

National Foreword

I.S. EN 55011:2016 is the adopted Irish version of the European Document EN 55011:2016, Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 55011

April 2016

ICS 33.100.10

Supersedes EN 55011:2009

English Version

Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement (CISPR 11:2015 , modified)

Appareils industriels, scientifiques et médicaux - Caractéristiques de perturbations radioélectriques - Limites et méthodes de mesure (CISPR 11:2015 , modifiée)

Industrielle, wissenschaftliche und medizinische Geräte - Funkstörungen - Grenzwerte und Messverfahren (CISPR 11:2015 , modifiziert)

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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

The text of document CISPR/B/628/FDIS, future edition 6 of CISPR 11, prepared by CISPR SC B "Interference relating to industrial, scientific and medical radio-frequency apparatus, to other (heavy) industrial equipment, to overhead power lines, to high voltage equipment and to electric traction" of CISPR "International special committee on radio interference" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 55011:2016.

A draft amendment, which covers common modifications to CISPR 11:2015 (CISPR/B/628/FDIS), was prepared by CLC/TC 210," Electromagnetic Compatibility (EMC)" and approved by CENELEC.

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)	2017-02-15
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-02-15

This document supersedes EN 55011:2009.

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Clauses, subclauses, notes, tables, figures and annexes which are additional to those in CISPR 11:2015 are prefixed “Z”.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s), see informative Annex ZZ, which is an integral part of this document.

CISPR 11

Edition 6.0 2015-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE
COMITÉ INTERNATIONAL SPÉCIAL DES PERTURBATIONS RADIOÉLECTRIQUES

Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement

Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure

CISPR 11:2015-06(en-fr)

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CISPR 11

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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

INDUSTRIAL, SCIENTIFIC AND MEDICAL EQUIPMENT – RADIO-FREQUENCY DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard CISPR 11 has been prepared by CISPR Subcommittee B: Interference relating to industrial, scientific and medical radio-frequency apparatus, to other (heavy) industrial equipment, to overhead power lines, to high voltage equipment and to electric traction.

This sixth edition cancels and replaces the fifth edition published in 2009 and its Amendment 1 published in 2010. It constitutes a technical revision.

It introduces and permits type testing on components of power electronic equipment, systems and installations. Its emission limits apply now to low voltage (LV) a.c. and d.c. power ports, irrespective of the direction of power transmission. Several limits were adapted to the practical test conditions found at test sites. They are also applicable now to power electronic ISM RF equipment used for wireless power transfer (WPT), for instant power supply and charging purposes. The limits in the range 1 GHz to 18 GHz apply now to CW-type disturbances and to fluctuating disturbances in a similar, uniform and technology-neutral way.

For these measurements, two alternative methods of measurement are available, the traditional log-AV method and the new APD method.

For measurements at LV d.c. power ports of power electronic equipment, a modern implementation of the 150 Ω Delta-network specified in CISPR 16-1-2 has been made available.

This International Standard CISPR 11 has the status of a Product Family EMC standard in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications (2014)*.

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

FDIS	Report on voting
CISPR/B/628/FDIS	CISPR/B/631/RVD

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

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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The main content of this standard is based on CISPR Recommendation No. 39/2 given below:

RECOMMENDATION No. 39/2

Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment

The CISPR

CONSIDERING

a) that ISM RF equipment is an important source of disturbance;

b) that methods of measuring such disturbances have been prescribed by the CISPR;

c) that certain frequencies are designated by the International Telecommunication Union (ITU) for unrestricted radiation from ISM equipment,

RECOMMENDS

that the latest edition of CISPR 11 be used for the application of limits and methods of measurement of ISM equipment.

INTRODUCTION

This CISPR publication contains, amongst common requirements for the control of RF disturbances from equipment intended for use in industrial, scientific, and medical electrical applications, specific requirements for the control of RF disturbances caused by ISM RF applications in the meaning of the definition of the International Telecommunication Union (ITU), see also Definition 3.13 in this International Standard. CISPR and ITU share their responsibility for the protection of radio services in respect of the use of ISM RF applications.

The CISPR is concerned with the control of RF disturbances from ISM RF applications by means of an assessment of these disturbances either at a standardised test site or, for an individual ISM RF application which cannot be tested at such a site, at its place of operation. Consequently, this CISPR Publication covers requirements for conformity assessment of both, equipment assessed by means of type tests at standardised test sites or of individual equipment under in situ conditions.

The ITU is concerned with the control of RF disturbances from ISM RF applications during normal operation and use of the respective equipment at its place of operation (see Definition 1.15 in the ITU Radio Regulations). There, use of radio-frequency energy decoupled from the ISM RF application by radiation, induction or capacitive coupling is restricted to the location of that individual application.

This CISPR publication contains, in 6.3, the essential emission requirements for an assessment of RF disturbances from ISM RF applications at standardised test sites. These requirements allow for type testing of ISM RF applications operated at frequencies up to 18 GHz. It further contains, in 6.4, the essential emission requirements for an in situ assessment of RF disturbances from individual ISM RF applications in the frequency range up to 1 GHz. All requirements were established in close collaboration with the ITU and enjoy approval of the ITU.

However, for operation and use of several types of ISM RF applications the manufacturer, installer and/or customer should be aware of additional national provisions regarding possible licensing and particular protection needs of local radio services and applications. Depending on the country concerned, such additional provisions may apply to individual ISM RF applications operated at frequencies outsides designated ISM bands (see Table 1). They also may apply to ISM RF applications operated at frequencies above 18 GHz. For the latter type of applications, local protection of radio services and appliances requires an accomplishment of the conformity assessment by application of the relevant national provisions in the frequency range above 18 GHz in accordance with vested interests of the ITU and national administrations. These additional national provisions may apply to spurious emissions, emissions appearing at harmonics of the operation frequency, and to wanted emissions at the operation frequency allocated outside a designated ISM band in the frequency range above 18 GHz.

Recommendations of CISPR for the protection of radio services in particular areas are found in Annex E of this International Standard.

Definition 1.15 of the ITU Radio Regulations reads as follows:

1.15 *industrial, scientific and medical (ISM) applications (of radio frequency energy)*: Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.

[ITU Radio Regulations Volume 1: 2012 – Chapter I, Definition 1.15]

INDUSTRIAL, SCIENTIFIC AND MEDICAL EQUIPMENT – RADIO-FREQUENCY DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT

1 Scope

This International Standard applies to industrial, scientific and medical electrical equipment operating in the frequency range 0 Hz to 400 GHz and to domestic and similar appliances designed to generate and/or use locally radio-frequency energy.

This standard covers emission requirements related to radio-frequency (RF) disturbances in the frequency range of 9 kHz to 400 GHz. Measurements need only be performed in frequency ranges where limits are specified in Clause 6.

For ISM RF applications in the meaning of the definition found in the ITU Radio Regulations (see Definition 3.13), this standard covers emission requirements related to radio-frequency disturbances in the frequency range of 9 kHz to 18 GHz.

NOTE Emission requirements for induction cooking appliances are specified in CISPR 14-1 [1][1].

Requirements for ISM RF lighting equipment and UV irradiators operating at frequencies within the ISM frequency bands defined by the ITU Radio Regulations are contained in this standard.

Equipment covered by other CISPR product and product family emission standards are excluded from the scope of this standard.

2 Normative references

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

CISPR 16-1-1:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*
CISPR 16-1-1:2010/AMD 1:2010
CISPR 16-1-1:2010/AMD 2:2014

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

CISPR 16-1-4:2010, *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*
CISPR 16-1-4:2010/AMD 1:2012

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1 Figures in square brackets refer to the Bibliography.

CISPR 16-2-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR 16-2-3:2010, *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/AMD 1:2010
CISPR 16-2-3:2010/AMD 2:2014

CISPR 16-4-2:2011, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Measuring instrumentation uncertainty*
CISPR 16-4-2:2011/AMD 1:2014

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 60601-1-2:2014, *Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic disturbances – Requirements and tests*

IEC 60601-2-2:2009, *Medical electrical equipment – Part 2-2: Particular requirements for the basic safety and essential performance of high frequency surgical equipment and high frequency surgical accessories*

IEC 60974-10:2014, *Arc welding equipment – Part 10: Electromagnetic compatibility (EMC) requirements*

IEC 61307:2011, *Industrial microwave heating installations – Test methods for the determination of power output*

IEC 62135-2:2007, *Resistance welding equipment – Part 2: Electromagnetic compatibility (EMC) requirements*

ITU Radio Regulations (2012), *Radio regulations, Volume 3 – Resolutions and recommendations, Resolution no. 63* (available at http://www.itu.int/pub/R-REG-RR-2012)

3 Terms and definitions

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

3.1
a.c. mains power port
port used to connect to a public low voltage a.c. mains power distribution network or other low voltage a.c. mains installation

3.2
arc welding equipment
equipment for applying current and voltage and having the required characteristics suitable for arc welding and allied processes

3.3
artificial mains network
AMN
network that provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver and decouples the test circuit from the supply mains

Note 1 to entry: There are two basic types of AMN, the V-network (V-AMN) which couples the unsymmetrical voltages, and the Delta-network which couples the symmetric and the asymmetric voltages separately.

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

3.4
boundary of the equipment under test
imaginary straight line periphery describing a simple geometric configuration encompassing the equipment under test

Note 1 to entry: All interconnecting cables are included within this boundary.

3.5
component
product which serves a specific function or functions and which is intended for use in a higher order assembled equipment or system

3.6
d.c. artificial network
artificial d.c. network
DC-AN
artificial network that provides defined termination to the EUT's d.c. power port under test while also providing the necessary decoupling from conducted disturbances originating from the laboratory d.c. power source or from the load

3.7
d.c. power port
port used to connect to a low voltage d.c. power generating system or energy storage, or to another source/load

Note 1 to entry: Such a system may be for example a photovoltaic or a fuel cell power generating system, or also a battery.

3.8
electro-discharge machining (EDM) equipment
EDM equipment
all the necessary units for the spark erosion process including the machine tool, the generator, control circuits, the working fluid container and integral devices

3.9
electromagnetic radiation
1) phenomenon by which energy in the form of electromagnetic waves emanates from a source into space

2) energy transferred through space in the form of electromagnetic waves

Note 1 to entry: By extension, the term "electromagnetic radiation" sometimes also covers induction phenomena.

[SOURCE: IEC 60050-161:1990, 161-01-10]

3.10
equipment for resistance welding and allied processes
all equipment associated with carrying out the processes of resistance welding or allied processes consisting of e.g. power source, electrodes, tooling and associated control equipment, which may be a separate unit or part of a complex machine

3.11
grid connected power converter
GCPC
power converter connected to an a.c. mains power distribution network or other a.c. mains installation and used in a power generating system

3.12
high power electronic system and equipment
one or more semiconductor power converters with a combined rated power greater than 75 kVA, or an equipment containing such converters

Note 1 to entry: Examples of such high power electronic equipment are semiconductor power converters for application in UPS (Uninterruptible Power Systems) and PDS (Power Drive Systems).

3.13
industrial, scientific and medical (ISM) applications (of radio frequency energy)
ISM applications (of radio frequency energy)
operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications

Note 1 to entry: Typical applications are the production of physical, biological, or chemical effects such as heating, ionisation of gases, mechanical vibrations, hair removal, acceleration of charged particles. A non-exhaustive list of examples is given in Annex A.

[SOURCE: ITU Radio Regulations Volume 1: 2012 – Chapter I, Definition 1.15]

3.14
ISM RF equipment and appliances
equipment or appliances designed to generate and/or use locally radio-frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications and information technology and other applications covered by other CISPR publications

Note 2 to entry: The abbreviation “ISM RF” is used throughout this standard for such equipment or appliances only.

3.15
low voltage
LV
a set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c. or 1 500 V d.c.

[SOURCE: IEC 60050-601:1985, 601-01-26, modified – addition of the words "or 1 500 V d.c."]

3.16
photovoltaic power generating system
electric power generating system which uses the photovoltaic effect to convert solar power into electricity

3.17
small size equipment
equipment, either positioned on a table top or standing on the floor which, including its cables fits in an imaginary cylindrical test volume of 1,2 m in diameter and 1,5 m height (to ground plane)

3.18
spark erosion
removal of material in a dielectric working fluid by electro-discharges, which are separated in time and randomly distributed in space, between two electrically conductive electrodes (the tool electrode and the work piece electrode), and where the energy in the discharge is controlled

3.19
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

Note 1 to entry: Recognition of a type test as type approval may depend on national or regional regulation, see H.2 in Annex H.

4 Frequencies designated for ISM use

Certain frequencies are designated by the International Telecommunication Union (ITU) for use as fundamental frequencies for ISM RF applications (see also Definition 3.13). These frequencies are listed in Table 1.

NOTE In individual countries different or additional frequencies can be designated for use by ISM RF applications.

Table 1 – Frequencies in the radio-frequency (RF) range designated by ITU for use as fundamental ISM frequencies

Centre frequency MHz	**Frequency range** MHz	**Maximum radiation limit** [b]	**Number of appropriate footnote to the table of frequency allocation of the ITU Radio Regulations** [a]
6,780	6,765 – 6,795	Under consideration	5.138
13,560	13,553 – 13,567	Unrestricted	5.150
27,120	26,957 – 27,283	Unrestricted	5.150
40,680	40,66 – 40,70	Unrestricted	5.150
433,920	433,05 – 434,79	Under consideration	5.138 in Region 1, except countries mentioned in 5.280
915,000	902 – 928	Unrestricted	5.150 in Region 2 only
2 450	2 400 – 2 500	Unrestricted	5.150
5 800	5 725 – 5 875	Unrestricted	5.150
24 125	24 000 – 24 250	Unrestricted	5.150
61 250	61 000 – 61 500	Under consideration	5.138
122 500	122 000 – 123 000	Under consideration	5.138
245 000	244 000 – 246 000	Under consideration	5.138

[a] Resolution No. 63 of the ITU Radio Regulations applies.

[b] The term “unrestricted” applies to the fundamental and all other frequency components falling within the designated band. Outside of ITU designated ISM bands the limits for the disturbance voltage and radiation disturbance in this standard apply.

5 Classification of equipment

5.1 Separation into groups

In order to simplify identification of the relevant limits, equipment in the scope of this standard is categorized into two groups, i.e. into group 1 and group 2.

Group 1 equipment: group 1 contains all equipment in the scope of this standard which is not classified as group 2 equipment.

Group 2 equipment: group 2 contains all ISM RF equipment in which radio-frequency energy in the frequency range 9 kHz to 400 GHz is intentionally generated and used or only used locally, in the form of electromagnetic radiation, inductive and/or capacitive coupling, for the treatment of material, for inspection/analysis purposes, or for transfer of electromagnetic energy.

NOTE See Annex A for examples of the separation of equipment into group 1 or 2.

5.2 Division into classes

In accordance with the intended use of equipment in the electromagnetic environment, this standard defines two classes of equipment, namely class A and class B.

Class A equipment is equipment suitable for use in all locations other than those allocated in residential environments and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

Class A equipment shall meet class A limits.

Arc welding equipment which contains arc striking or stabilizing devices and stand-alone arc striking or stabilizing devices for arc welding shall be classified as class A equipment.

Class B equipment is equipment suitable for use in locations in residential environments and in establishments directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

Class B equipment shall meet class B limits.

5.3 Documentation for the user

The manufacturer and/or supplier of equipment shall ensure that the user is informed about the class and group of the equipment, either by labelling or by the accompanying documentation. In both cases the manufacturer/supplier shall explain the meaning of both the class and the group in the documentation accompanying the equipment.

The documentation accompanying the equipment shall contain details of any precautions to be observed by the purchaser or user to ensure that regular operation and use of the equipment in the field does not cause harmful radio frequency interference (RFI). In the framework of this standard, these details concern information about:

- the possibility of radio frequency interference originating from operation of class A equipment in certain environments,
- special precautions to be observed when connecting class A equipment to a low voltage power supply network, see Footnote a and b in Table 2, Footnote b in Table 3 and Footnote a in Table 6, respectively,
- measures which can be taken at installation level to reduce emissions from installed class A equipment, see Footnote b in Table 2 and Footnote a in Table 8.

For class A equipment, the instructions for use accompanying the product shall contain the following text:

> **Caution:** This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.

6 Limits of electromagnetic disturbances

6.1 General

For measurements at standardized test sites, the requirements specified hereafter constitute the requirements for type tests.

Class A equipment may be measured either on a test site or in situ as preferred by the manufacturer.

NOTE 1 Due to size, complexity or operating conditions some equipment may have to be measured in situ in order to show compliance with the radiation disturbance limits specified herein.

Class B equipment shall be measured on a test site.

NOTE 2 The limits have been determined on a probabilistic basis taking into account the likelihood of interference. In cases of interference, additional provisions may have to be applied.

The lower limit shall apply at all transition frequencies.

Measuring apparatus and methods of measurement are specified in Clauses 7, 8 and 9.

6.2 Group 1 equipment measured on a test site

6.2.1 Limits for conducted disturbances

6.2.1.1 General

The equipment under test shall meet either:

a) both the average limit specified for measurements with an average detector and the quasi-peak limit specified for measurements with a quasi-peak detector (see 7.3); or
b) the average limit when using a quasi-peak detector (see 7.3).

The limits for the LV d.c. power port specified hereafter apply only to grid connected power convertors (GCPCs) intended for assembly into photovoltaic power generating systems.

6.2.1.2 Frequency range 9 kHz to 150 kHz

In the frequency range 9 kHz to 150 kHz limits are not specified.

6.2.1.3 Frequency range 150 kHz to 30 MHz

Limits for the disturbance voltage at low voltage a.c. mains power ports in the frequency range 150 kHz to 30 MHz for equipment measured on a test site using the 50 Ω/50 μH CISPR artificial mains network (V-AMN) or the CISPR voltage probe (see 7.3.3 and Figure 1) are given in Tables 2 and 4.

Limits for conducted disturbances at low voltage d.c. power ports in the frequency range 150 kHz to 30 MHz for equipment measured on a test site using the 150 Ω CISPR network (DC-AN) (see 7.3.2.3 and Annex I) or the current probe (see CISPR 16-1-2) are given in Table 3 and 5.

Table 2 – Disturbance voltage limits for class A group 1 equipment measured on a test site (a.c. mains power port)

Frequency range MHz	**Rated power of ≤ 20 kVA** [c]		**Rated power of > 20 kVA and ≤ 75 kVA** [a, c]		**High power electronic systems and equipment, Rated power of > 75 kVA** [b, c]	
	Quasi-peak dB(μV)	**Average** dB(μV)	**Quasi-peak** dB(μV)	**Average** dB(μV)	**Quasi-peak** dB(μV)	**Average** dB(μV)
0,15 – 0,50	79	66	100	90	130	120
0,50 – 5	73	60	86	76	125	115
5 – 30	73	60	90 decreasing linearly with logarithm of frequency to 73	80 decreasing linearly with logarithm of frequency to 60	115	105

At the transition frequency, the more stringent limit shall apply.

For class A equipment intended to be connected solely to isolated neutral or high impedance earthed (IT) industrial power distribution networks (see IEC 60364-1) the limits for equipment with a rated power > 75 kVA may be applied, regardless of its actual rated power.

NOTE A rated input or output power of 20 kVA corresponds for example to a current of approximately 29 A per phase in case of 400 V three-phase power supply networks, and to a current of approximately 58 A per phase in case of 200 V three phase power supply networks.

a These limits apply to equipment with a rated power > 20 kVA and intended to be connected to a dedicated power transformer or generator, and which is not connected to low voltage (LV) overhead power lines. For equipment not intended to be connected to a user specific power transformer the limits for ≤ 20 kVA apply. The manufacturer, and/or supplier shall provide information on installation measures that can be used to reduce emissions from the installed equipment. In particular it shall be indicated that this equipment is intended to be connected to a dedicated power transformer or generator and not to LV overhead power lines.

b These limits apply only to high power electronic systems and equipment with a rated power greater than 75 kVA when intended to be installed as follows:

- installation is supplied from a dedicated power transformer or generator, and which is not connected to Low Voltage (LV) overhead power lines,
- installation is physically separated from residential environments by distance greater than 30 m or by a structure which acts as a barrier to radiated phenomena,
- the manufacturer and/or supplier shall indicate that this equipment meets the disturbance voltage limits for high power electronic systems and equipment of rated input power > 75 kVA and provide information on installation measures to be applied by the installer. In particular, it shall be indicated that this equipment is intended to be used in an installation which is powered by a dedicated power transformer or generator and not by LV overhead power lines.

c Selection of the appropriate set of limits shall be based on the rated a.c. power stated by the manufacturer.

Table 3 – Limits for conducted disturbances of class A group 1 equipment measured on a test site (d.c. power port)

Frequency range MHz	Rated power of ≤ 20 kVA [a]		Rated power of > 20 kVA to ≤ 75 kVA [a, b]				Rated power of > 75 kVA [a, b]			
	Voltage limits		Voltage limits		Current limits		Voltage limits		Current limits	
	QP dB(μV)	AV dB(μV)	QP dB(μV)	AV dB(μV)	QP dB(μA)	AV dB(μA)	QP dB(μV)	AV dB(μV)	QP dB(μA)	AV dB(μA)
0,15 to 5	97 to 89	84 to 76	116 to 106	106 to 96	72 to 62	62 to 52	132 to 122	122 to 112	88 to 78	78 to 68
5 to 30	89	76	106 to 89	96 to 76	62 to 45	52 to 32	122 to 105	112 to 92	78 to 61	68 to 48

In certain frequency ranges, the limits in this table decrease linearly with logarithm of frequency.

[a] Selection of the appropriate set of limits shall be based on the rated a.c. power stated by the manufacturer.

[b] These limits apply to equipment with a rated power > 20 kVA and intended to be installed in a large photovoltaic power generating system by a professional. In the manual accompanying the product, the manufacturer, and/or supplier shall provide information on mitigation measures that can be used to reduce emissions from the installed equipment, with the goal of preventing harmful interference to radio reception in a distance of 30 m from the installation. In particular it shall be indicated that this equipment can be equipped with additional filtering and that installation is physically separated from residential environments by distance greater than 30 m. The installer is invited to check the mitigated installation against CISPR 11 in-situ measurements as indicated in clause 6.4 of this standard.

Table 4 – Disturbance voltage limits for class B group 1 equipment measured on a test site (a.c. mains power port)

Frequency range MHz	Quasi-peak dB(μV)	Average dB(μV)
0,15 – 0,50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46
0,50 – 5	56	46
5 – 30	60	50

At the transition frequency, the more stringent limit shall apply.

For diagnostic X-ray generators operating in intermittent mode the quasi-peak limits of Table 2 or Table 4 can be relaxed by 20 dB.

Table 5 – Disturbance voltage limits for class B group 1 equipment measured on a test site (d.c. power port)

Frequency range MHz	Quasi-peak dB(μV)	Average dB(μV)
0,15 – 0,50	84 Decreasing linearly with logarithm of frequency to 74	74 Decreasing linearly with logarithm of frequency to 64
0,50 – 30	74	64

6.2.2 Limits of electromagnetic radiation disturbance

6.2.2.1 General

The equipment under test shall meet the quasi-peak limits when using a quasi-peak detector.

6.2.2.2 Frequency range 9 kHz to 150 kHz

In the frequency range 9 kHz to 150 kHz limits are not specified.

6.2.2.3 Frequency range 150 kHz to 1 GHz

In the frequency range 150 kHz to 30 MHz limits are not specified.

In the frequency range above 30 MHz the limits refer to the electric field strength component of the electromagnetic radiation disturbance.

The electromagnetic radiation disturbance limits for the frequency range 30 MHz to 1 GHz for group 1, classes A and B equipment are specified in Table 6 and 7, respectively. Recommendations for the protection of specific safety-related radio services are given in Annex E and Table E.1.

On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m (see information in Table 6), and class B equipment at a nominal distance of 3 m, or 10 m (see information in Table 7). A measuring distance less than 10 m is allowed only for equipment which complies with the definition for *small size equipment* given in 3.17.

Table 6 – Electromagnetic radiation disturbance limits for class A group 1 equipment measured on a test site

Frequency range MHz	10 m measuring distance rated power of		3 m measuring distance [b] rated power of	
	≤ 20 kVA [c]	> 20 kVA [a, c]	≤ 20 kVA [c]	> 20 kVA [a, c]
	Quasi-peak dB(μV/m)	Quasi-peak dB(μV/m)	Quasi-peak dB(μV/m)	Quasi-peak dB(μV/m)
30 – 230	40	50	50	60
230 – 1 000	47	50	57	60

On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m. In case of measurements at a separation distance of 30 m, an inverse proportionality factor of 20 dB per decade shall be used to normalize the measured data to the specified distance for determining compliance.

At the transition frequency, the more stringent limit shall apply.

[a] These limits apply to equipment with a rated power of > 20 kVA and intended to be used at locations where there is a distance greater than 30 m between the equipment and third party sensitive radio communications. The manufacturer shall indicate in the technical documentation that this equipment is intended to be used at locations where the separation distance to third party sensitive radio services is > 30 m. If these conditions are not met, then the limits for ≤ 20 kVA apply.

[b] The 3 m separation distance applies only to small size equipment meeting the size criterion defined in 3.17.

[c] Selection of the appropriate set of limits shall be based on the rated a.c. power stated by the manufacturer.

Table 7 – Electromagnetic radiation disturbance limits for class B group 1 equipment measured on a test site

Frequency range MHz	10 m measuring distance Quasi-peak dB(μV/m)	3 m measuring distance [a] Quasi-peak dB(μV/m)
30 – 230	30	40
230 – 1 000	37	47
On a test site, class B equipment can be measured at a nominal distance of 3 m or 10 m. At the transition frequency, the more stringent limit shall apply.		
[a] The 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.		

For medical electrical equipment intended to be permanently installed in shielded locations, further provisions with regard to the measurement arrangement and load conditions are found in IEC 60601-1-2.

6.2.2.4 Frequency range 1 GHz to 18 GHz

In the frequency range 1 GHz to 18 GHz limits are not specified.

6.2.2.5 Frequency range 18 GHz to 400 GHz

In the frequency range 18 GHz to 400 GHz limits are not specified.

6.3 Group 2 equipment measured on a test site

6.3.1 Limits for conducted disturbances

6.3.1.1 General

The equipment under test shall meet either:

a) both the average limit specified for measurements with an average detector and the quasi-peak limit specified for measurements with a quasi-peak detector (see 7.3); or
b) the average limit when using a quasi-peak detector (see 7.3).

6.3.1.2 Frequency range 9 kHz to 150 kHz

In the frequency range 9 kHz to 150 kHz limits are not specified.

6.3.1.3 Frequency range 150 kHz to 30 MHz

Limits for the disturbance voltage at low voltage a.c. mains power ports in the frequency range 150 kHz to 30 MHz for equipment measured on a test site using the 50 Ω/50 μH CISPR artificial mains network (V-AMN) or the CISPR voltage probe (see 7.3.3 and Figure 1) are given in Tables 8 and 9, except for the ITU designated frequency bands listed in Table 1 where no limits apply.

For electric welding equipment the limits of Table 8 or 9 apply in active mode of operation. In stand-by (or idle) mode, the limits of Table 2 or 4 apply.

For ISM RF lighting devices operating in dedicated ISM frequency bands (defined by the ITU in Table 1) the limits of Table 9 apply.

Table 8 – Disturbance voltage limits for class A group 2 equipment measured on a test site (a.c. mains power port)

<table>
<tr><th rowspan="2">Frequency range
MHz</th><th colspan="2">Rated power of
≤ 75 kVA [b]</th><th colspan="2">Rated power of
> 75 kVA [a, b]</th></tr>
<tr><th>Quasi-peak
dB(μV)</th><th>Average
dB(μV)</th><th>Quasi-peak
dB(μV)</th><th>Average
dB(μV)</th></tr>
<tr><td>0,15 – 0,50</td><td>100</td><td>90</td><td>130</td><td>120</td></tr>
<tr><td>0,50 – 5</td><td>86</td><td>76</td><td>125</td><td>115</td></tr>
<tr><td>5 – 30</td><td>90
decreasing linearly with logarithm of frequency to
73</td><td>80
decreasing linearly with logarithm of frequency to
60</td><td>115</td><td>105</td></tr>
<tr><td colspan="5">At the transition frequency, the more stringent limit shall apply.
For class A equipment with a rated power ≤ 75 kVA intended to be connected solely to isolated neutral or high impedance earthed (IT) industrial power distribution networks (see IEC 60364-1) the limits defined for group 2 equipment with a rated power > 75 kVA may be applied.</td></tr>
<tr><td colspan="5">[a] The manufacturer and/or supplier shall provide information on installation measures that can be used to reduce emissions from the installed equipment.
[b] Selection of the appropriate set of limits shall be based on the rated a.c. power stated by the manufacturer.</td></tr>
</table>

NOTE A rated input or output power of 75 kVA corresponds for example to a current of approximately 108 A per phase in case of 400 V three phase power supply networks and to a current of approximately 216 A per phase in case of 200 V three phase power supply networks.

High-frequency (HF) surgical equipment shall meet the limits of Table 2 or 4 specified for group 1 equipment, in stand-by mode of operation. For high-frequency (HF) surgical equipment operating at frequencies outside designated ISM bands (see Table 1), these limits also apply at the operating frequency and inside the designated frequency bands. The related measurements shall be performed in a test arrangement in accordance with IEC 60601-2-2.

Table 9 – Disturbance voltage limits for class B group 2 equipment measured on a test site (a.c. mains power port)

Frequency range MHz	Quasi-peak dB(μV)	Average dB(μV)
0,15 – 0,50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46
0,50 – 5	56	46
5 – 30	60	50
At the transition frequency, the more stringent limit shall apply.		

6.3.2 Limits of electromagnetic radiation disturbance

6.3.2.1 General

The equipment under test shall meet the limits when using a measuring instrument with a peak, quasi-peak or average detector as indicated in the appropriate table.

Up to 30 MHz the limits refer to the magnetic component of the electromagnetic radiation disturbance. Above 30 MHz the limits refer to the electric field strength component of the electromagnetic radiation disturbance.

6.3.2.2 Frequency range 9 kHz to 150 kHz

In the frequency range 9 kHz to 150 kHz limits are not specified.

6.3.2.3 Frequency range 150 kHz to 1 GHz

Except for the designated frequency range listed in Table 1, the electromagnetic radiation disturbance limits for the frequency range 150 kHz to 1 GHz for group 2 class A equipment are specified in Table 10; and for group 2 class B equipment in Table 12.

The limits in Tables 10 and 12 apply to all electromagnetic disturbances at all frequencies not exempted according to Table 1 Footnote b).

For class A resistance welding equipment the limits of Table 10 apply in the frequency range 30 MHz to 1 GHz in active mode of operation. In stand-by (or idle) mode, the limits of Table 6 apply. For class B resistance welding equipment the limits of Table 12 apply in active mode of operation. In stand-by (or idle) mode, the limits of Table 7 apply.

For class A arc welding equipment the limits of Table 11 apply in active mode of operation. In stand-by (or idle) mode, the limits of Table 6 apply. For class B arc welding equipment the limits of Table 7 apply in active mode of operation and in stand-by (or idle) mode.

For class A EDM equipment the limits of Table 11 apply.

For ISM RF lighting devices operating in dedicated ISM frequency bands (defined by the ITU in Table 1) the limits of Table 12 apply.

For high-frequency (HF) surgical equipment, the limits of Table 6 or 7 apply. High-frequency (HF) surgical equipment shall meet the respective limits when tested in stand-by mode of operation.

Recommendations for the protection of specific safety services are given in Annex E and Table E.1.

On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m, and class B equipment at a nominal distance of 3 m or 10 m (see Tables 10 and 12).

In the frequency range 30 MHz to 1 GHz, a measuring distance less than 10 m is allowed only for equipment which complies with the definition given in 3.17.

Table 10 – Electromagnetic radiation disturbance limits for class A group 2 equipment measured on a test site

Frequency range MHz	Limits for a measuring distance *D* in m					
	On a test site *D* = 30 m from the equipment		On a test site *D* = 10 m from the equipment		On a test site *D* = 3 m from the equipment [a]	
	Electric field Quasi-peak dB(μV/m)	Magnetic field Quasi-peak dB(μA/m)	Electric field Quasi-peak dB(μV/m)	Magnetic field Quasi-peak dB(μA/m)	Electric field Quasi-peak dB(μV/m)	Magnetic field Quasi-peak dB(μA/m)
0,15 – 0,49	–	33,5	–	57,5	–	82
0,49 – 1,705	–	23,5	–	47,5	–	72
1,705 – 2,194	–	28,5	–	52,5	–	77
2,194 – 3,95	–	23,5	–	43,5	–	68
3,95 – 11	–	8,5	–	18,5	–	43,5 decreasing linearly with logarithm of frequency to 28,5
11 – 20	–	8,5	–	18,5	–	28,5
20 – 30	–	-1,5	–	8,5	–	18,5
30 – 47	58	–	68	–	78	–
47 – 53,91	40	–	50	–	60	–
53,91 – 54,56	40	–	50	–	60	–
54,56 – 68	40	–	50	–	60	–
68 – 80,872	53	–	63	–	73	–
80,872 – 81,848	68	–	78	–	88	–
81,848 – 87	53	–	63	–	73	–
87 – 134,786	50	–	60	–	70	–
134,786 – 136,414	60	–	70	–	80	–
136,414 – 156	50	–	60	–	70	–
156 – 174	64	–	74	–	84	–
174 – 188,7	40	–	50	–	60	–
188,7 – 190,979	50	–	60	–	70	–
190,979 – 230	40	–	50	–	60	–
230 – 400	50	–	60	–	70	–
400 – 470	53	–	63	–	73	–
470 – 1 000	50	–	60	–	70	–

On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m. A measuring distance less than 10 m is allowed only for equipment which complies with the definition given in 3.17.

At the transition frequency, the more stringent limit shall apply.

[a] In the frequency range 30 MHz to 1 GHz, the 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.

Table 11 – Electromagnetic radiation disturbance limits for class A EDM and arc welding equipment measured on a test site

Frequency range MHz	Limits for a measuring distance *D* in m	
	D = 10 m	*D* = 3 m [a]
	Quasi-peak dB(μV/m)	Quasi-peak dB(μV/m)
30 – 230	80 Decreasing linearly with logarithm of frequency to 60	90 Decreasing linearly with logarithm of frequency to 70
230 – 1 000	60	70
On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m. In case of measurements at a separation distance of 30 m, an inverse proportionality factor of 20 dB per decade shall be used to normalize the measured data to the specified distance for determining compliance.		
[a] The 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.		

Table 12 – Electromagnetic radiation disturbance limits for class B group 2 equipment measured on a test site

Frequency range MHz	Limits for a measuring distance *D* in m				
	Electric field				Magnetic field
	D = 10 m		*D* = 3 m [b]		*D* = 3 m
	Quasi-peak	Average [a]	Quasi-peak	Average [a]	Quasi-peak
	dB(μV/m)		dB(μV/m)		dB(μA/m)
0,15 – 30	–	–	–	–	39 Decreasing linearly with the logarithm of frequency to 3
30 – 80,872	30	25	40	35	–
80,872 – 81,848	50	45	60	55	–
81,848 – 134,786	30	25	40	35	–
134,786 – 136,414	50	45	60	55	–
136,414 – 230	30	25	40	35	–
230 – 1 000	37	32	47	42	–
On a test site, class B equipment can be measured at a nominal distance of 3 m or 10 m. In the frequency range 30 MHz to 1 GHz, a measuring distance less than 10 m is allowed only for equipment which complies with the definition given in 3.17. At the transition frequency, the more stringent limit should apply.					
[a] The average limits apply to magnetron driven equipment and microwave ovens only. If magnetron driven equipment or microwave ovens exceed the quasi-peak limit at certain frequencies, then the measurement shall be repeated at these frequencies with the average detector and the average limits specified in this table apply. [b] In the frequency range 30 MHz to 1 GHz, the 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.					

6.3.2.4 Frequency range 1 GHz to 18 GHz

The limits in the frequency range 1 GHz to 18 GHz apply only to group 2 equipment operating at frequencies above 400 MHz. The limits specified in the Tables 13 to 15 apply only to RF disturbances appearing outside designated ISM bands as listed in Table 1.

The electromagnetic radiation disturbance limits for the frequency range 1 GHz to 18 GHz are specified in Tables 13 to 15. The equipment shall meet either the limits of Table 13, or at least the limits of Table 14 or Table 15 (see decision tree in 9.4.1, Figure 12).

ISM RF lighting devices operating in dedicated ISM frequency bands (defined by the ITU in Table 1) shall either meet the class B limits of Table 13 or at least the limits of Table 14.

For microwave-powered UV irradiators, the limits specified in Table 13 apply.

Recommendations for the protection of specific safety services are given in Annex E and Table E.1.

Table 13 – Electromagnetic radiation disturbance peak limits for group 2 equipment operating at frequencies above 400 MHz

Frequency range GHz	**Limits for a measurement distance of 3 m** **Peak** dB(μV/m)	
1 – 18	**Class A**	**Class B**
Within harmonic frequency bands	82 [a]	70
Outside harmonic frequency bands	70	70
11,7 – 12,7	73 [b]	73 [b]
Peak measurements with a resolution bandwidth of 1 MHz and a video signal bandwidth (VBW) higher than or equal to 1 MHz. The recommended VBW is 3 MHz. NOTE In this table, "harmonic frequency bands" means the frequency bands which are multiples of the ISM bands allocated above 1 GHz.		
[a] At the upper and lower edge frequency of harmonic frequency bands, the more stringent limit of 70 dB(μV/m) applies. [b] In the satellite radio broadcasting band, the measured disturbance values shall not exceed 73 dB(μV/m).		

Table 14 – Electromagnetic radiation disturbance weighted limits for group 2 equipment operating at frequencies above 400 MHz

Frequency range GHz	**Limits for a measuring distance of 3 m** **Peak** dB(μV/m)
1 – 2,4	60
2,5 – 5,725	60
5,875 – 18	60

Weighted measurements shall be performed with a resolution bandwidth of 1 MHz and a video bandwidth of 10 Hz.

To check conformance with the limits of this table, weighted measurements shall be performed in all of the following frequency ranges, in which the limit of Table 13 was exceeded during the peak measurement:

a) 1 005 MHz – 2 395 MHz (1 000 MHz – 2 400 MHz)*;

b) 2 505 MHz – 6 125 MHz (outside the band 5 720 MHz – 5 880 MHz)*;

c) 6 125 MHz – 8 575 MHz;

d) 8 575 MHz – 11 025 MHz;

e) 11 025 MHz – 13 475 MHz;

f) 13 475 MHz – 15 925 MHz;

g) 15 925 MHz – 17 995 MHz*.

At sub-ranges where the limit of Table 13 was exceeded, a weighted measurement shall be performed with a span of 10 MHz around the centre frequency adjusted to the frequency of the highest disturbance level in the respective sub-range.

* In cases where the frequency of highest emission during peak measurement is found closer than 5 MHz from the frequency edges 1 GHz, 2,4 GHz, 2,5 GHz, 5,72 GHz, 5,88 GHz or 18 GHz, the span for weighted measurements shall remain 10 MHz but in such case the centre frequency shall be adjusted so that the frequency edges are not exceeded.

NOTE See annex B for further guidance on the use of the spectrum analyser.

Table 15 – Electromagnetic radiation disturbance APD level corresponding to 10^{-1} limits for class B group 2 equipment operating at frequencies above 400 MHz

Frequency range GHz	**Limits for a measurement distance of 3 m** **APD level corresponding to 10^{-1}** dB(μV/m)
1 – 2,4	70
2,5 – 5,725	70
5,875 – 18	70

APD measurements with a resolution bandwidth of 1 MHz and a video signal bandwidth higher than or equal to 1 MHz.

NOTE An APD level corresponding to 10^{-1} means that the amplitude of the disturbance exceeds the specified level during the observation time with a probability of 10 %.

6.4 Group 1 and group 2 class A equipment measured in situ

6.4.1 Limits for conducted disturbances

Under *in situ* conditions, an assessment of conducted disturbances is not required.

6.4.2 Limits of electromagnetic radiation disturbance

The limits given in Table 16 apply to class A group 1 equipment and the limits given in Table 17 apply to class A group 2 equipment.

Table 16 – Electromagnetic radiation disturbance limits for class A group 1 equipment measured *in situ*

Frequency range MHz	**Limits with measuring distance 30 m from the outer face of the exterior wall of the building in which the equipment is situated**	
	Electric field **Quasi-peak** dB(μV/m)	**Magnetic field** **Quasi-peak** [a] dB(μA/m)
0,15 – 0,49	–	13,5
0,49 – 3,95	–	3,5
3,95 – 20	–	–11,5
20 – 30	–	–21,5
30 – 230	30	–
230 – 1 000	37	–

At the transition frequency, the more stringent limit shall apply.

If local conditions do not allow for measurements at 30 m, then a larger distance can be used. In this case, an inverse proportionality factor of 20 dB per decade shall be used to normalize the measured data to the specified distance for determining compliance.

[a] These limits apply in addition to the limits in the frequency range 30 MHz to 1 GHz to radiated disturbances originating from the operation frequency and its harmonics appearing in the frequency range 150 kHz to 30 MHz, caused by the installed class A group 1 equipment with a rated power exceeding 20 kVA. In the event that the ambient noise level exceeds the above limits, the emissions of the EUT shall not increase this noise floor by more than 3 dB.

Table 17 – Electromagnetic radiation disturbance limits for class A group 2 equipment measured *in situ*

Frequency range MHz	Limits for a measuring distance of D in m from the exterior wall of the building	
	Electric field **Quasi-peak** dB(μV/m)	**Magnetic field** **Quasi-peak** dB(μA/m)
0,15 – 0,49	–	23,5
0,49 – 1,705	–	13,5
1,705 – 2,194	–	18,5
2,194 – 3,95	–	13,5
3,95 – 20	–	–1,5
20 – 30	–	–11,5
30 – 47	48	–
47 – 53,91	30	–
53,91 – 54,56	30	–
54,56 – 68	30	–
68 – 80,872	43	–
80,872 – 81,848	58	–
81,848 – 87	43	–
87 – 134,786	40	–
134,786-136,414	50	–
136,414 – 156	40	–
156 – 174	54	–
174 – 188,7	30	–
188,7 – 190,979	40	–
190,979 – 230	30	–
230 – 400	40	–
400 – 470	43	–
470 – 1000	40	–
At the transition frequency, the more stringent limit shall apply.		

For group 2 equipment measured *in situ*, the measuring distance D from the exterior wall of the building in which the equipment is situated equals $(30 + x/a)$ m or 100 m whichever is smaller, provided that the measuring distance D is within the boundary of the premises. In the case where the calculated distance D is beyond the boundary of the premises, the measuring distance D equals x or 30 m, whichever is longer.

For the calculation of the above values:

x is the nearest distance between the exterior wall of the building in which the equipment is situated and the boundary of the user's premises in each measuring direction;

a = 2,5 for frequencies lower than 1 MHz;

a = 4,5 for frequencies equal to or higher than 1 MHz.

7 Measurement requirements

7.1 General

The requirements specified in this clause, together with the limits specified in Clause 6, constitute the essential EMC requirements of this standard. For measurements at test sites (see Clause 8), verification of compliance of a given type of equipment with these essential EMC requirements qualifies as *type test*.

Requirements which relate to measurements at such test sites are type test requirements. A type test may be recognized as type approval if the conditions for the statistical assessment of measurement results according to Annex H are observed.

Class A equipment may be measured either on a test site or *in situ* as determined by the manufacturer. Class B equipment shall be measured on a test site.

Specific requirements for making measurements on a test site are given in Clauses 8 and 9, for making measurements *in situ* in Clause 10.

The requirements of the present clause are to be met for both, test site and/or *in situ* measurements.

Measurements need only be performed in frequency ranges where limits are specified in Clause 6.

Components or subassemblies for higher order equipment or systems which are intended to be assembled at their respective place of operation only can also be tested according to the requirements of this standard. For testing purposes in the framework of this standard, such components or subassemblies shall be regarded as stand-alone equipment. Components or subassemblies for which compliance with the relevant requirements cannot be shown when measured at a test site can also be assessed *in situ* when being installed into the higher order system, in which case the provisions of 6.4 shall apply.

NOTE 1 The environments encompassed in this standard are residential, commercial or industrial environments as described in IEC 61000-2-5 [11][2]. Adherence of equipment to the requirements of this standard will allow for its operation and use in these environments without resulting in an increased risk of RFI. There may also exist other IEC product standards which allow for compliance testing of components or subassemblies of higher order systems but which encompass other environments than those specified in IEC 61000-2-5 [11]. Choice of this standard or the other appropriate IEC product standard for compliance testing of components or subassemblies is up to the manufacturer.

NOTE 2 Examples for such components include, but are not limited to power converters used for distributed generation and supply of electric energy into LV a.c. mains networks or installations or, by means of their own dedicated transformer, into MV power distribution networks, but also power electric subassemblies intended for supply of higher order systems with power from LV a.c. mains networks.

7.2 Ambient noise

A test site for type testing shall allow emissions from the equipment under test to be distinguished from ambient noise. The suitability in this respect can be determined by measuring the ambient noise levels with the equipment under test inoperative and ensuring that the ambient noise levels are at least 6 dB below the limits specified in 6.2 or 6.3, as appropriate for the measurement being carried out. Further information on compliance testing in the presence of ambient noise is found in CISPR 16-2-1:2014, 6.2.2 and CISPR 16-2-3:2010, 6.2.2.

It is not necessary to reduce the ambient noise level to 6 dB below the specified limit where the combination of the ambient noise plus the emission from the equipment under test does

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2 Figures in square brackets refer to the Bibliography.

not exceed the specified limit. Under these conditions the equipment under test is considered to satisfy the specified limit.

When carrying out measurements of conducted RF disturbances, local radio transmissions may increase the ambient noise level at some frequencies. A suitable radio-frequency filter may be inserted between the artificial network (V-AMN and/or DC-AN) and the respective laboratory a.c. mains supply or d.c. power source, or measurements may be performed in a shielded enclosure. The components forming the radio-frequency filter should be enclosed in a metallic screen directly connected to the reference ground of the measuring system. The requirements for the impedance of the artificial network shall be satisfied at the frequency of measurement when the radio-frequency filter is connected.

If, when measuring radiated RF disturbances, the 6 dB ambient noise conditions cannot be met, then the antenna may be located at a distance closer to the equipment under test than specified in Clause 6 (see 8.3.4). Further advice on measurement conditions in presence of high level ambient noise is found in Annex C.

7.3 Measuring equipment

7.3.1 Measuring instruments

Receivers with quasi-peak detectors shall be in accordance with CISPR 16-1-1. Receivers with average detectors shall be in accordance with CISPR 16-1-1.

NOTE 1 Both detectors can be incorporated in a single receiver and measurements carried out by alternately using the quasi-peak detector and the average detector.

NOTE 2 The average detector in CISPR 16-1-1 is commonly referred to as “CISPR-Average”. This is to emphasize that the average detector used in a CISPR receiver obtains a measurement result that is equivalent to the peak reading of a meter with a time constant as defined in CISPR 16-1-1.

The measuring receiver used shall be operated in such a way that a variation in frequency of the disturbance being measured does not affect the results.

NOTE 3 Measuring instruments having other detector characteristics can be used provided the measurement of the disturbance values can be proved to be the same. Attention is drawn to the convenience of using a panoramic receiver or a spectrum analyzer, particularly if the working frequency of the equipment under test changes appreciably during the work cycle.

To avoid the possibility of the measuring instrument incorrectly indicating non-compliance with the limits, the measuring receiver shall not be tuned closer to the edge of one of the bands designated for ISM use than the frequency at which its 6 dB bandwidth point aligns with the edge of the designated band.

When making measurements on high power equipment, care should be taken to ensure that screening and the spurious response rejection characteristics of the measuring receiver are adequate.

For measurements at frequencies above 1 GHz, a spectrum analyser with characteristics as defined in CISPR 16-1-1 shall be used.

Precautions which can be taken in the use of a spectrum analyzer are given in Annex B.

7.3.2 Artificial network (AN)

7.3.2.1 General

The artificial network (AN) is required to provide a defined termination impedance for the EUT’s a.c. mains power port or d.c. power port under test at radio frequencies at the point of measurement. The AN will also provide isolation of the equipment under test from ambient noise on the respective a.c. or d.c. power lines.

7.3.2.2 Artificial mains network (AMN)

Measurement of the disturbance voltage at low voltage a.c. mains power ports shall be made using an artificial mains network (V-AMN) as specified in CISPR 16-1-2.

7.3.2.3 Artificial d.c. network (DC-AN)

Measurement of the disturbance voltage at low voltage d.c. power ports shall be made either using the 150 Ω artificial mains Delta-network specified in 4.7 of CISPR 16-1-2:2014 (see also CISPR 16-1-2:2014, Figure A.2) or the 150 Ω artificial d.c. network specified in Annex I of this standard. For simplified wording, any of these networks intended for use with measurements at low voltage d.c. power ports is further on denoted as DC-AN.

7.3.3 Voltage probe

The voltage probe shown in Figure 1 shall be used when the artificial mains network (V-AMN) cannot be used. The probe is connected sequentially between each line and the reference earth chosen (metal plate, metal tube). The probe consists mainly of a decoupling capacitor and a resistor such that the total resistance between the line and earth is at least 1 500 Ω. The effect on the accuracy of measurement of the capacitor or any other device which may be used to protect the measuring receiver against dangerous currents shall be either less than 1 dB or allowed for in calibration. The voltage probe shall meet the requirements specified in CISPR 16-1-2:2014, Clause 5.

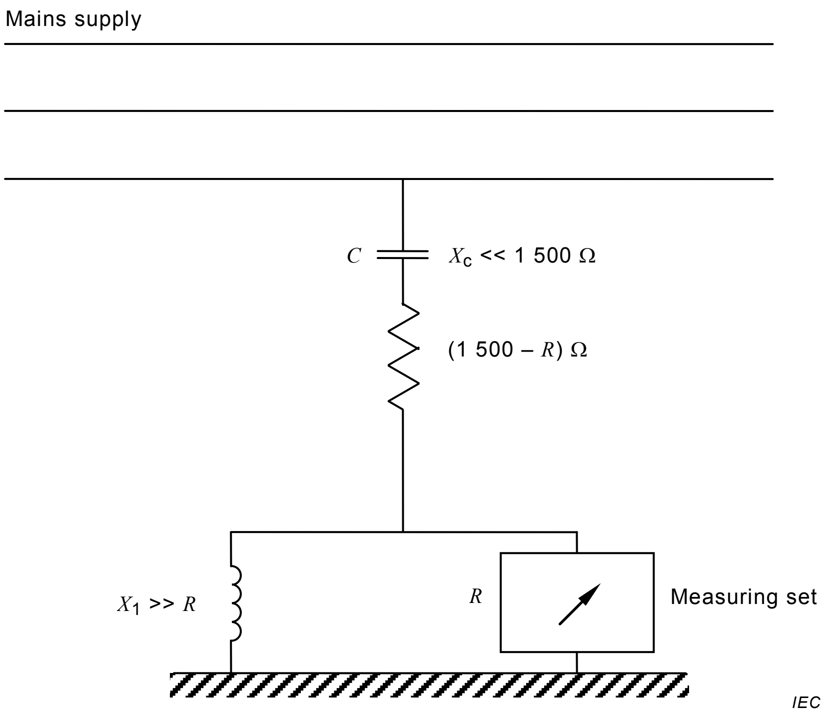


Figure 1 – Circuit for disturbance voltage measurements on mains supply

7.3.4 Antennas

7.3.4.1 Frequency range below 30 MHz

In the frequency range below 30 MHz the antenna shall be a loop as specified in CISPR 16-1-4. The antenna shall be supported in the vertical plane and be rotatable about a vertical axis. The lowest point of the loop shall be 1 m above ground level.

7.3.4.2 Frequency range from 30 MHz to 1 GHz

In the frequency range from 30 MHz to 1 GHz the antenna used shall be as specified in CISPR 16-1-4. Measurements shall be made for both horizontal and vertical polarization. The nearest point of the antenna to the ground shall be not less than 0,2 m.

For measurements on a test site the centre of the antenna shall be varied between 1 m and 4 m height for maximum indication at each test frequency.

For measurements *in situ* the centre of the antenna shall be fixed at (2,0 ±0,2) m height above the ground.

NOTE Other antennas can be used provided the results can be shown to be within ±2 dB of the results which would have been obtained using a balanced dipole antenna.

7.3.4.3 Frequency range above 1 GHz

For measurements at frequencies above 1 GHz, the antenna used shall be as specified in CISPR 16-1-4.

7.3.5 Artificial hand

In order to simulate the influence of the user's hand, application of the artificial hand is required for hand-held equipment during the mains disturbance voltage measurement.

The artificial hand consists of metal foil which is connected to one terminal (terminal M) of an RC element consisting of a capacitor of 220 pF ± 20 % in series with a resistance of 510 Ω ± 10 % (see Figure 2); the other terminal of the RC element shall be connected to the reference ground of the measuring system (see CISPR 16-1-2). The RC element of the artificial hand may be incorporated in the housing of the artificial mains network.

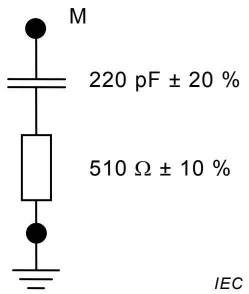


Figure 2 – Artificial hand, RC element

7.4 Frequency measurement

For equipment which is intended to operate with a fundamental frequency in one of the designated bands listed in Table 1, the frequency shall be checked with measuring equipment having an inherent error of measurement not greater than 1/10 of the permissible tolerance for the mid-band frequency of the designated band. The frequency shall be measured over all the load range from the lowest power normally used up to the maximum.

7.5 Configuration of equipment under test

7.5.1 General

Consistent with typical applications of the equipment under test, the level of the disturbance shall be maximized by varying the configuration of the equipment. An example of a typical setup for measurements of radiated disturbances from a table-top EUT is provided in

Figure 3. The measurement arrangement shall be typical of normal installation practice and centred to the turntable's vertical axis.

NOTE 1 The extent to which this subclause is applicable to the measurement of an installation *in situ* will depend on the flexibility inherent in each particular installation. The provisions of this subclause apply to *in situ* measurements in so far as a particular installation allows for the position of cables to be varied and different units within the installation to be operated independently, the extent to which the position of the installation can be moved within the premises, etc.

For measurement of radiated disturbances with a separation distance of 3 m the assessment of the radiation from the cabling of the EUT shall be restricted to those fractions of interconnecting cables (see 7.5.2) and mains cables (see 7.5.3) which are within the test volume of 1,2 m diameter times 1,5 m height above ground. Peripheral equipment not fitting into the test volume shall be excluded from the measurements or decoupled from the test environment.

NOTE 2 Restriction of radiation assessment to the cable fractions inside the test volume can be achieved for example by application of CMADs at the cables at the position where they leave the test volume. CISPR 16-2-3 gives further guidance on the application of CMADs.

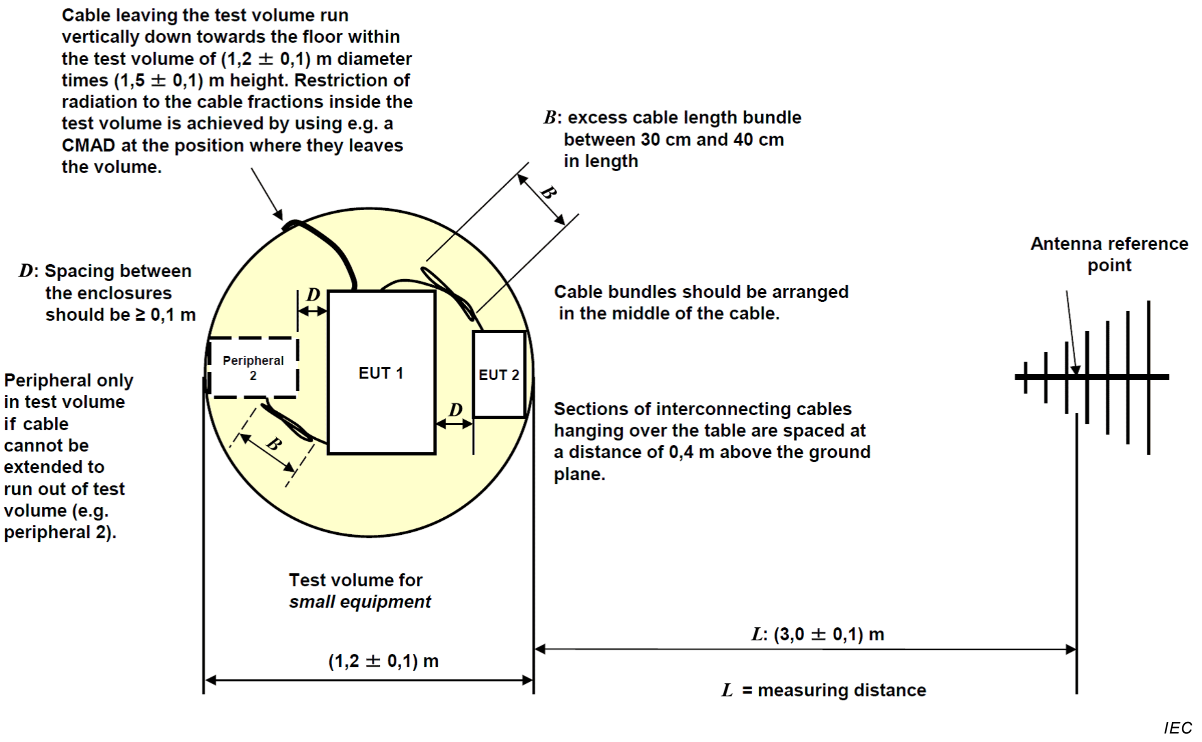


Figure 3a – Top view

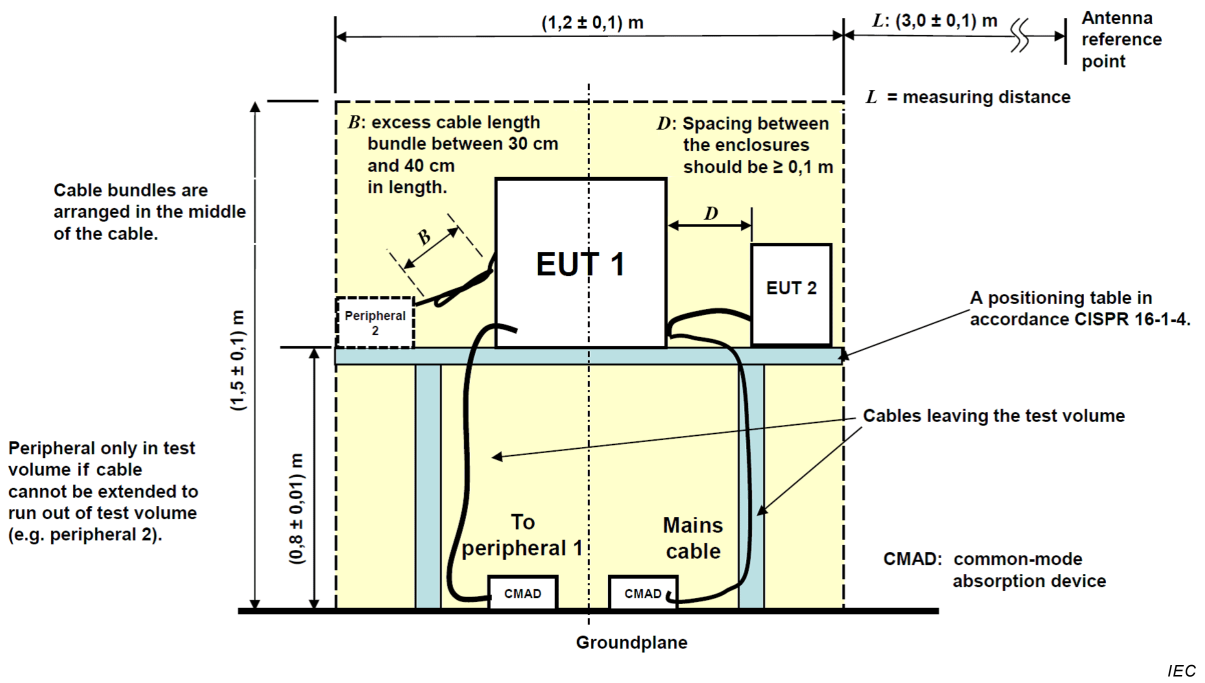


Figure 3b – Side view

Figure 3 – Example for a typical cable arrangement for measurements of radiated disturbances in 3 m separation distance, Table-top EUT

An example of a typical unified test set up for floor standing equipment suitable for measurement of conducted as well as radiated disturbances is shown in Figure 4. Further examples of typical arrangements of the EUT and associated peripherals are given in CISPR 16-2-3 and CISPR 16-2-1.

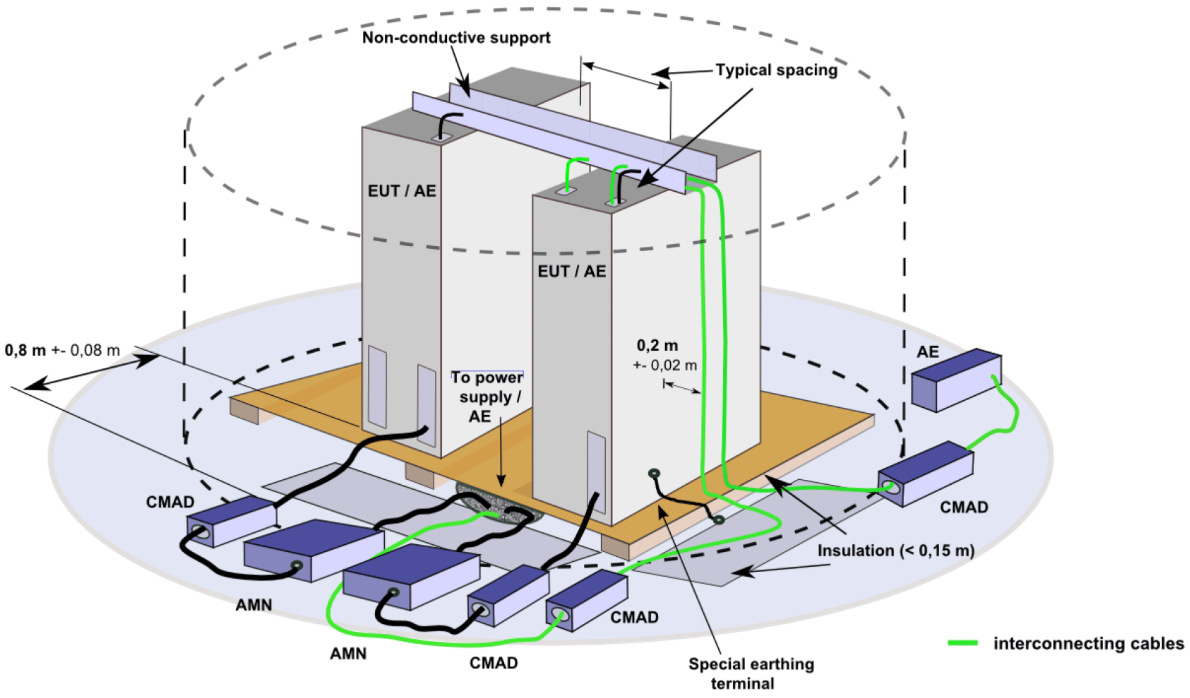


Figure 4 – Example for a typical test set up for measurement of conducted and/or radiated disturbances from a floor standing EUT, 3D view

The configuration of the equipment under test shall be precisely documented in the test report.

7.5.2 Interconnecting cables

This subclause applies to equipment in which there are interconnecting cables between various parts of the equipment, or systems where a number of components are interconnected.

NOTE 1 The observation of all provisions in this subclause permits the application of the results of an evaluation to a number of system configurations using the same types of equipment and cables as tested, but no other, each system configuration being in effect a subsystem of the one evaluated.

Interconnecting cables shall 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 emission when performing field strength measurements.

If shielded or special cables are used during the tests then the use of such cables shall be specified in the instruction manual.

The connection of signal leads, except for the leads supplied by the manufacturer, is not required during radio-frequency emission measurements for portable test and measurement apparatus, group 1, or those intended for use in laboratories and operated by competent persons. Examples are signal generators, network and logic analysers, and spectrum analysers.

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

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

Any set of results shall be accompanied by a complete description of the cable and equipment orientation so that results can be repeated. If there are conditions of use, those conditions shall be specified, documented and included in the instructions for use.

If a given type of equipment can perform separately any one of a number of functions then the equipment shall be tested while performing each of these functions. For systems which may include a number of different components, one of each type of component which is included in the system configuration shall be included in the evaluation.

A system which contains a number of identical components, but has been evaluated using only one of those components, does not require further evaluation if the initial evaluation was satisfactory.

NOTE 2 This is possible because it has been found that in practice emissions from identical modules are not additive.

When equipment is being evaluated which interacts with other equipment to form a system then the evaluation may be carried out using either additional equipment to represent the total system or with the use of simulators. In either method care shall be taken to ensure that the equipment under test is evaluated with the effects of the rest of the system or simulators satisfying the ambient noise conditions specified in 7.2. Any simulator used in lieu of actual equipment shall properly represent the electrical and in some cases the mechanical characteristics of the interface, especially with respect to radio-frequency signals and impedances, as well as cable configuration and types.

NOTE 3 This procedure is required to facilitate the evaluation of equipment which will be combined with other equipment from different manufacturers to form a system.

7.5.3 Connection to the electricity supply network on a test site

7.5.3.1 Connection to the laboratory a.c. mains network

7.5.3.1.1 General

Where necessary the mains power from the laboratory's electricity power supply network shall be provided through the artificial mains network (AMN) specified in 7.3.2.2.

For connection to the AMN or to the test site's electricity supply network, appropriate lengths of mains cables shall be used. If the manufacturer's installation instructions specify a particular type of mains cable for use with the EUT, connection to the AMN or to the test site's electricity supply network shall be made with that cable type.

Mains power at the nominal voltage shall be supplied.

7.5.3.1.2 Connection to the laboratory a.c. mains network for measurement of conducted disturbances and for radiated disturbances in the range up to 30 MHz

When performing measurements on a test site, the artificial mains network (V-AMN) specified in 7.3.2.2 is to be used whenever possible. The enclosure of the V-AMN shall be located so that its closest surface is no less than 0,8 m from the nearest boundary of the equipment under test.

Where a flexible mains cord is provided by the manufacturer this shall be 1 m long or, if in excess of 1 m, the excess cable shall be folded to and forth to form a bundle not exceeding 0,4 m in length.

Where a mains cable is specified in the manufacturer's installation instructions a 1 m length of the type specified shall be connected between the test unit and the AMN.

Earth connections, where required for safety purposes, shall be connected to the reference “earth” point of the AMN and where not otherwise provided or specified by the manufacturer shall be 1 m long and run parallel to the mains connection at a distance of not more than 0,1 m.

Other earth connections (e.g. for EMC purposes) either specified or supplied by the manufacturer for connection to the same terminal as the safety earth connection shall also be connected to the reference earth of the AMN.

Ancillary low voltage a.c. mains ports shall be connected to the laboratory a.c. mains network via one or more separate artificial mains networks (V-AMN) as specified in 7.3.2.2.

Where the equipment under test is a system comprising more than one unit, each unit having its own power cord, the point of connection for the AMN is determined from the following rules:

a) each mains cable which is terminated in a mains supply plug of a standard design (e.g., IEC 60083) shall be tested separately;
b) mains cables or terminals which are not specified by the manufacturer to be connected to another unit in the system for the purposes of supplying mains power shall be tested separately;
c) mains cables or terminals which are specified by the manufacturer to be connected to another unit in the system for the purposes of supplying mains power shall be connected to that unit, and the mains cables or terminals of that unit are connected to the AMN;
d) where a special connection is specified, the necessary hardware to effect the connection shall be used during the evaluation of the equipment under test.

7.5.3.1.3 Connection to the laboratory a.c. mains network for measurement of radiated disturbances in the range 30 MHz to 18 GHz

Connection to the laboratory's electricity supply network may be provided with or without the use of an AMN allocated inside the test environment, see Figure 4. For measurement arrangements not including an AMN, grounding and earthing of the EUT shall be guaranteed by adherence to the principles set out in 7.5.3.1.2 as far as possible.

If the measurement arrangement does not include an AMN, then excessive lengths of mains cables do not need to be bundled and allocated inside the test volume. They may be accommodated someplace outside the test volume or test environment. For decoupling of radiation from these excessive cable lengths it is however recommended to carefully terminate these mains cables at the location where they leave the test volume. For this decoupling use of CMADs is recommended. For measurements with a separation distance of 3 m this decoupling is mandatory, see 7.5.1.

7.5.3.2 Connection to the laboratory d.c. power supply or other d.c. power source

When performing measurements on a test site, the 150 Ω artificial d.c. network (DC-AN) specified in 7.3.2.3 is to be used whenever possible. The enclosure of the DC-AN shall be located so that its closest surface is 0,8 m from the nearest boundary of the equipment under test.

Where the DC-AN is used as voltage probe, the EUT’s d.c. power port under test shall be decoupled from the d.c. power source by means of suitable common mode decoupling devices such as ferrite tubes, CMADs or a CDN as specified in 6.2.4 of IEC 61000-4-6:2013 which are to be clamped at or to be inserted in the d.c. power cable connecting the d.c. power source with the measurement arrangement for the EUT, see also Figure 7, 8 and 9 in

8.2.2.2.3. If a CDN according to IEC 61000-4-6 is used for decoupling purposes, its RF power input port shall not be terminated with a 50 Ω resistive load.

Connection is to be made to a suitable d.c. power source. The d.c. output voltage of this power source shall be adjustable to provide a voltage level within the rated operation range for the respective type of EUT.

NOTE 1 For supply of the EUT's d.c. power port under test, a dedicated laboratory d.c. power source, appropriate (sets of) batteries or also other d.c. energy sources such as e. g. fuel cell modules can be used, provided that they allow for continuous and stable voltage, current, etc. necessary for power converters under rated output operating conditions, throughout the measurement.

Care should be taken when selecting the laboratory d.c. power source and installing it in the measurement arrangement. It is recommended to select and install only such a d.c. power source which provides for a good galvanic insulation and also sufficient RF decoupling of both d.c. power terminals from the laboratory reference ground plane. Internal decoupling capacitors at the d.c. power source's terminals used for internal suppression of asymmetrical disturbances may provide an unwanted bypass for the common mode 150 Ω termination impedance of the DC-AN used for the measurements. This may cause saturation effects in the mitigation filter of the power converter under test, in particular at the operation frequency (i.e. the switching frequency) of the power converter and its harmonics, which are usually allocated in the range from 2 kHz to some 20 kHz. Saturated mitigation filters do however lead to incorrect and invalid measurement results, since the power converter is not operated as intended, during the measurements. For guidance on prevention of saturation effects caused by the configuration of the test site, see information in Annex K.

Where a particular type of d.c. power cable is specified in the manufacturer's installation instructions, this shall be used during testing.

For testing, a cable length as short as possible shall be connected between the equipment under test and the DC-AN respecting the proximity of the boundary conditions defined above.

Where the equipment under test has more than one d.c. power port of the same type, the number of d.c. power ports needed to operate the equipment at its rated power shall be connected to the DC-AN for the measurements. All other d.c. power ports shall be terminated with a suitable 150 Ω common mode termination impedance. Multiple ports galvanically connected in parallel (such as bus bars or strips for connection to multiple cables) are considered to represent one single port only.

NOTE 2 For these other terminations, any suitable device can be used. This includes e.g. use of further 150 Ω networks according to CISPR 16-1-2, further DC-ANs as specified in 7.3.2.3, or also use of 150 Ω coupling/ decoupling devices (CDN) as defined in IEC 61000-4-6.

Ancillary d.c. power ports shall be connected to an appropriate separate laboratory d.c. power source or battery, via a suitable 150 Ω common mode termination impedance.

NOTE 3 If a separate mains-connected laboratory d.c. power source is used, then it can be appropriate to also insert another EMI filter in the connection to that power source. Diagrams showing suitable setups for the test site are found in Annex J.

7.6 Load conditions of equipment under test

7.6.1 General

Load conditions of the equipment under test are specified in this subclause. Equipment not covered by this subclause are to be operated so as to maximize the disturbance generated while still conforming with normal operating procedures as provided in the operating manual of the equipment.

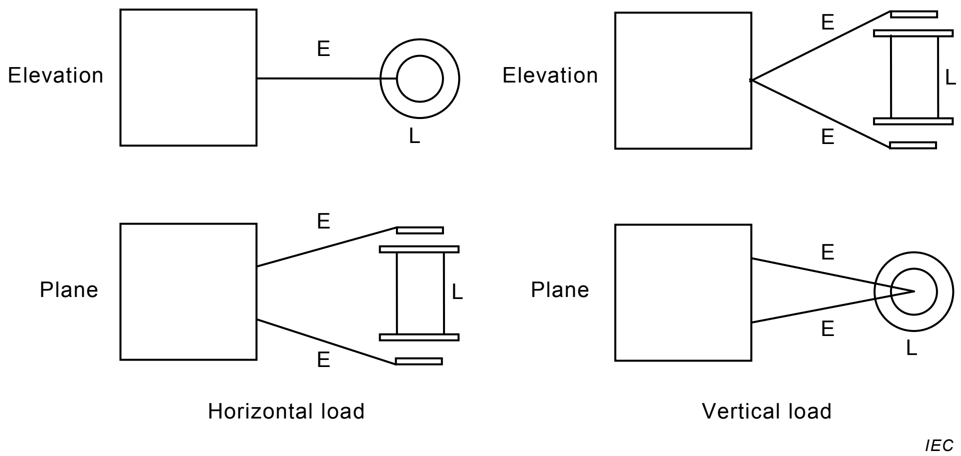
7.6.2 Medical equipment

7.6.2.1 Therapeutic equipment using frequencies from 0,15 MHz to 400 MHz

All measurements shall be made under operating conditions as provided for in the operating manual of the equipment. The output circuit to be used to load the equipment depends on the nature of the electrodes with which it is to be used.

For equipment of the capacitive type, a dummy load shall be used for the measurements. The general arrangement is shown in Figure 5. The dummy load shall be substantially resistive and capable of absorbing the rated maximum output power of the equipment.

The two terminals of the dummy load shall be at opposite ends of the load and each terminal shall be joined directly to a circular flat metal plate having a diameter of 170 mm ±10 mm. Measurements shall be made with each of the output cables and capacitive electrodes supplied with the equipment. The capacitive electrodes are to be disposed parallel to the circular metal plates at the ends of the dummy load, the spacing between them being adjusted to produce the appropriate power dissipation in the dummy load.



E = electrode arms and cables

L = dummy load

Figure 5 – Disposition of medical (capacitive type) and dummy load

Measurements shall be made with the dummy load both horizontal and vertical (see Figure 5). In each case, the equipment, together with the output cables, capacitive electrodes and dummy load, shall be rotated around its vertical axis during measurements of electromagnetic radiation disturbance in order that the maximum value can be measured.

NOTE The following arrangement of lamps has been found suitable for testing many types of equipment in the power range tested:

a) nominal output power 100 W to 300 W:

four lamps 110 V/60 W in parallel, or five lamps 125 V/60 W in parallel;

b) nominal output power 300 W to 500 W:

four lamps 125 V/100 W in parallel, or five lamps 150 V/100 W in parallel.

For equipment of the inductive type, measurements shall be made using the cables and coils supplied with the equipment for the treatment of the patient. The test load shall consist of a vertical tubular container of insulating material, having a diameter of 10 cm, filled to a height of 50 cm with a solution consisting of 9 g of sodium chloride to 1 litre of distilled water.

The container shall be placed within the coil with the axis of the container coincident with the axis of the coil. The centres of the coil and the liquid load shall also coincide.

Measurements shall be made at both maximum and half-maximum power and, where the output circuit can be tuned, it shall be tuned to resonance with the fundamental frequency of the equipment.

All measurements shall be made under all operating conditions as provided in the operating manual of the equipment.

7.6.2.2 UHF and microwave therapeutic equipment using frequencies above 400 MHz

Measurements shall be made with the output circuit of the equipment connected to a non-radiating resistive load having the same value as the characteristic impedance of the cable used to supply the equipment load.

7.6.2.3 Ultrasonic therapy equipment

Measurements shall be made with the transducer connected to the generator. The transducer shall be dipped in a non-metallic container having a diameter of about 10 cm and filled with distilled water.

Measurement shall be made at both maximum and half-maximum power and, where the output circuit can be tuned, it shall be tuned to resonance and then detuned. The specifications in the operating manual of the equipment are to be considered.

It is recommended to measure the maximum output of the equipment in accordance with the method published in IEC 61689 or using a derived arrangement, if necessary.

7.6.3 Industrial equipment

The load used when industrial equipment is tested may be either the load used in service or an equivalent device.

Where means for connecting auxiliary services such as water, gas, air, etc. are provided, connection of these services to the equipment under test shall be made by insulating tubing not less than 3 m long. When testing with the load used in service, the electrodes and cables shall be disposed in the manner of their normal use. Measurements shall be made at both maximum output power and at half-maximum output power. Equipment which will normally operate at zero or very low output power shall also be tested in these conditions.

Industrial induction heating and dielectric heating equipment should be tested in a configuration and with a load that is equivalent to actual or intended use. Where the equipment may be configured for a variety of loads or the load is not available, the load as specified in IEC 61922 for induction heating and IEC 61308 for dielectric heating equipment may be used. Industrial resistance heating equipment shall be tested with or without the charge, as specified by the manufacturer.

NOTE A circulating water load has been found suitable for many types of dielectric heating equipment.

Industrial microwave heating equipment shall conform to the limits of radiation in Clause 6 when loaded according to IEC 61307 or with a load used in practice. The load shall be varied as required to produce maximum power transfer, frequency variation or harmonic variation depending on the characteristics under examination.

7.6.4 Scientific, laboratory and measuring equipment

Scientific equipment shall be tested under normal operating conditions. Laboratory and measuring equipment shall be operated as intended. Any RF output ports shall be terminated in a matching non-radiating load.

7.6.5 Microwave cooking appliances

Microwave cooking appliances shall be operated with all normal components such as shelves in place, and with a load of 1 l of tap water initially at 20 °C ± 5 °C placed at the centre of the load-carrying surface provided by the manufacturer.

The water container shall be a cylindrical container of borosilicate glass of an external diameter of 190 mm ± 5 mm and a height of 90 mm ± 5 mm, see also IEC 60705.

Detailed information on the measurement procedure to be used in the frequency range above 1 GHz is found in 9.4.

7.6.6 Other equipment in the frequency range 1 GHz to 18 GHz

Other equipment shall conform to the limits of radiation in Clause 6 when tested with a dummy load consisting of a quantity of tap water in a non-conductive container. The size and shape of the container, its position in the equipment and the quantity of water contained therein shall be varied as required to produce maximum power transfer, frequency variation or harmonic radiation depending on the characteristics under examination.

7.6.7 Electric welding equipment

For arc welding equipment, the welding operation during the test is simulated by loading the equipment with a conventional load. Arc striking and stabilising devices shall be switched on during the emission measurements. The load conditions and the test configuration for arc welding equipment are specified in IEC 60974-10.

For resistance welding equipment, the welding operation during the test is simulated by short-circuiting the welding circuit. The load conditions and the test configuration for resistance welding equipment are specified in IEC 62135-2.

The start of the measurements according to this standard shall be delayed by up to 5 s after the welding equipment under test has been taken into operation.

7.6.8 ISM RF lighting equipment

ISM RF lighting equipment shall conform to the limits in 6.3 when tested as delivered by the manufacturer under normal operating conditions. In case of ISM RF lighting equipment, the EUT shall be operated until the magnetron oscillating frequency is stabilized. The start of any measurement according to this standard shall hence be delayed by at least 15 min.

7.6.9 Medium voltage (MV) and high voltage (HV) switchgear

For equipment used in medium or high voltage switchgear, the start of any measurements according to this standard shall be delayed until switching actions related to the main or primary circuit are finished (e.g. switching actions of breakers or disconnectors).

7.6.10 Grid connected power converters

7.6.10.1 Connection to the laboratory a.c. mains or similar load

The power converter under test shall be connected to the laboratory a.c. mains network via the artificial mains network (V-AMN) specified in 7.3.2.2, whenever possible. If such connection is not possible or not intended, then the power converter under test can be connected to an appropriate resistive load and the laboratory a.c. mains network in parallel, via the artificial mains network (V-AMN) specified in 7.3.2.2.

Connection to an appropriate resistive load is also recommended for power converters solely intended for use in island low voltage a.c. mains installations which are not connected to an other public low voltage a.c. mains power distribution network. For advice, consult the installation instructions of the manufacturer.

Alternatively the a.c. supply power for the laboratory d.c. power source can be taken from the a.c. output lines of the GCPC via the V-AMN without connecting the resistive load. The output a.c. power of the GCPC will be used to contribute to the required d.c. input power for that GCPC, thus the resistive load is not necessary in this case, see Figure J.1 in Annex J.

For suitable test site configurations, see Annex J.

7.6.10.2 Connection to another appropriate load

For power converters intended to be supplied from a.c. power sources, the d.c. power port under test shall be connected to a suitable resistive load or other adequate energy storage via an 150 Ω artificial network (DC-AN) as specified in 7.3.2.3. The EUT shall be connected to an appropriate load within the rated operational range for the respective type of EUT.

NOTE An example of a type of GCPC intended to be supplied from an a.c. power source is a power converter intended for assembly into an off-board charging station for electric vehicles (EV).

7.7 Recording of test-site measurement results

7.7.1 General

Any results obtained from measurements of conducted and/or radiated radio-frequency disturbances shall be recorded in the test report. If the results are not recorded in a continuous way and/or in graphical form over the frequency range observed, then the minimum requirements to the recordings set out in 7.7.2 and 7.7.3 shall apply.

The test report shall contain a statement underlining that the measurement instrumentation uncertainty (MIU) was determined according to CISPR 16-4-2 and was also considered when determining compliance with the limits for the tested individual equipment or the number of items in the sample of series-produced equipment.

The test report may include the numerical values of the MIU which the test laboratory has determined for each test performed. If the uncertainty budgets specified in CISPR 16-4-2 are exceeded, then the test report shall include the numerical values of the MIU of the test instrumentation actually used.

7.7.2 Conducted emissions

Of those conducted emissions above (L – 20 dB), where L is the limit level in logarithmic units, the record shall include at least the disturbance levels and the frequencies of the six highest disturbances in each observed frequency range from each mains port belonging to the EUT. The record shall also include an indication upon which conductor of the mains port carried the observed disturbance(s).

7.7.3 Radiated emissions

Of those radiated emissions above (L – 10 dB), where L is the limit level in logarithmic units, the record shall include at least the disturbance levels and the frequencies of the six highest disturbances in each observed frequency range. The record shall include the antenna polarization, antenna height and turntable rotation position if applicable for each reported disturbance. In case of test site measurements, the measurement distance actually selected and used (see 6.2.2 and 6.3.2) shall also be recorded in the test report.

8 Special provisions for test site measurements (9 kHz to 1 GHz)

8.1 Ground planes

A ground plane shall be used when making measurements on a test site. The relationship of the equipment under test to the ground plane shall be equivalent to that occurring in use. Except at the manufacturer's intended grounding locations, a floor standing EUT shall be insulated from the ground plane by a dielectric material with thickness of up to 15 cm. Direct connection to earth (i.e. to the ground plane) shall be done

a) either according to the manufacturer's instructions,

b) or, if the equipment under test is fitted with a special earthing terminal, then this terminal shall be connected to earth (i.e. be bonded to the ground plane) with a lead as short as possible, see also Figure 4.

A ground plane shall be used for radiation measurement and the measurement of disturbance voltages. The requirements for the radiation test site are given in 8.3 and, for the ground plane for the measurement of conducted disturbances, in 8.2.

8.2 Measurement of conducted disturbances

8.2.1 General

For the EUT's earthing and grounding conditions as well as connection to the laboratory's electricity supply network see 7.5.3.

The measurement of conducted disturbances shall be carried out using one of the following three options:

a) on the radiation test site with the equipment under test having the same configuration as used during the radiation measurement;

b) above a metal ground plane which shall extend at least 0,5 m beyond the boundary of the equipment under test and have a minimum size of 2 m × 2 m; or

c) within a screened room. Either the floor or one wall of the screened room shall act as the ground plane.

Option a) shall be used where the test site contains a metal ground plane. In options b) and c) the test unit, if non-floor-standing, shall be placed 0,4 m from the ground plane. Floor-standing test units shall be placed on the ground plane, the point(s) of contact being insulated from the ground plane but otherwise consistent with normal use. All test units shall be at least 0,8 m from any other metal surface.

The reference ground terminals of the artificial networks (V-AMNs and DC-ANs) used during the measurements shall be connected to the reference ground plane with a conductor as short as possible.

The power and signal cables shall be oriented in relation to the ground plane in a manner equivalent to actual use and precautions taken with the layout of the cables to ensure that spurious effects do not occur.

When the equipment under test is fitted with a special earthing terminal, this shall be connected to earth with a lead as short as possible. Equipment without earthing terminal shall be tested as normally connected, i.e. any earthing being obtained through the mains supply.

8.2.2 Measurements on grid connected power converters

8.2.2.1 Measurement of the disturbance voltage at a.c. power ports

The disturbance voltage at the low voltage a.c. power port of the power converter shall be measured using the usual method of measurement for disturbance voltages at a.c. mains ports, see also CISPR 16-2-1.

The disturbance voltage at the ancillary low voltage a.c. power port of the power converter, if applicable, shall be measured using the usual method of measurement for voltages at a.c. mains ports, see also CISPR 16-2-1.

For power converters which cannot be measured with the V-network (V-AMN), the disturbance voltage at the low voltage a.c. mains power port can be measured with the high-impedance voltage probe according to CISPR 16-1-2:2014, Clause 5. In this case, the laboratory a.c. power source shall be connected directly to the a.c. power port under test. For conditions of use of the high-impedance voltage probe, see 7.3.3.

Likewise, for measurements on power converters with a rated throughput power > 20 kVA, a V-network (V-AMN) can be used as a voltage probe as specified in 7.4.4.3 of CISPR 16-2-1:2014. The laboratory a.c. power source shall be connected to the a.c. power port under test via an inductance of 30 μH to 50 μH. The inductance may be realized by a choke, a power cable length of 50 m, or an isolation transformer. A suitable measurement arrangement is shown in Figure 8 and 9.

Compliance with the requirements of this standard can be shown in verifying that the limits of the disturbance voltage at a.c. mains power ports specified in Table 2 or in Table 4 are met.

8.2.2.2 Measurement of the disturbance voltage at d.c. power ports

8.2.2.2.1 General

Measurements at d.c. power ports only need to be performed on GCPCs intended for assembly into photovoltaic power generating systems.

Unless any specific operating condition is specified by the manufacturer, the input conditions for the EUT shall be adjusted resulting in maximum disturbance voltage levels.

NOTE The operating conditions, as defined by the manufacturer, are chosen to represent the worst case emissions.

Power converters with a rated throughput power > 20 kVA shall be measured while they are operated at an operational point for which feeding to the grid or providing output power to another appropriate load is possible. The d.c. input voltage shall be within the rated operation range.

Where the power converter is intended for connection to more than one d.c. power string and consequently is furnished with more than one d.c. power port, measurements of the disturbance voltage shall be performed in sequence at each of these ports. All other d.c. power ports not used during the respective measurement shall be terminated with a suitable 150 Ω common mode termination impedance, see 7.5.3.2. Multiple ports galvanically connected in parallel (such as bus bars or strips for connection to multiple cables) are considered to represent one single port only.

The disturbance voltage at the d.c. power port of the power converter shall be measured using the usual method of measurement for disturbance voltages at a.c. mains power ports, see also CISPR 16-2-1. This implies the following:

- Where unsymmetrical mode (UM) disturbance voltages are measured, compliance with the limits shall be verified for both measured unsymmetrical disturbance voltage levels, i.e. for the voltage levels measured from the plus terminal (pole) to reference ground and from the minus terminal (pole) to reference ground.

- Where common mode (CM) and differential mode (DM) disturbance voltages are measured, compliance with the limits shall be verified for measured disturbance voltage levels of both modes, i.e. for the level of the common mode (CM) disturbance voltage as well as for the level of the differential mode (DM) disturbance voltage.

If the DC-AN according to Annex I allows for measurement of UM, DM and CM disturbances, then it is sufficient to verify compliance with the limits either for UM disturbances (Method A), or for CM and DM disturbances (Method B). The choice of the method used for the measurement is left to the discretion of the user of this standard.

If the installation instructions accompanying the power converter contains information that the d.c. power port is solely intended for connection to

- a battery or other kind of local d.c. power source and/or;
- if the power converter and a battery or other kind of local d.c. power source is intended for incorporation in a higher order final equipment (comprising of one or more enclosures);

then this port can be exempted from the measurement.

8.2.2.2.2 Measurement procedure 1

8.2.2.2.2.1 General

The DC-AN is used as standardized 150 Ω common mode termination of the EUT and as decoupling network to the laboratory d.c. power source. A typical measurement arrangement is shown in Figure 6.

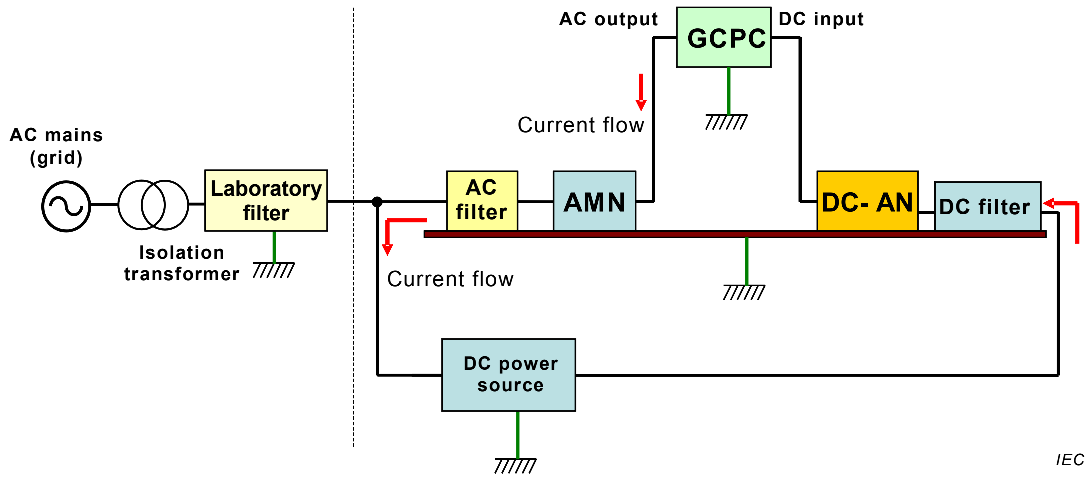


Figure 6 – Typical arrangement for measurement of conducted disturbances at LV d.c. power ports with the DC-AN used as termination and decoupling unit to the laboratory d.c. power source

8.2.2.2.2.2 Compliance criterion

Compliance with the requirements of CISPR 11 can be shown in verifying that the limits for the disturbance voltage specified in Table 3 or in Table 5 are met.

8.2.2.2.3 Measurement procedure 2

8.2.2.2.3.1 General

For measurements on power converters with a rated throughput power > 20 kVA, a DC-AN can be used as voltage probe. For an adequate decoupling of the EUT from the d.c. power source, the laboratory d.c. power source shall be connected to the d.c. power port under test via a common mode inductance of 90 µH to 150 µH. The common mode inductance may be realized by ferrite tubes, common mode absorbing devices, or a CDN as specified in 6.2.4 of IEC 61000-4-6:2013. Since a CDN according to IEC 61000-4-6 is used only as a decoupling network, its RF power input port shall not be terminated with a 50 Ω resistive load as shown in Figure 7.

NOTE It is up to the operator of the laboratory to ensure that the measurement results obtained with such measurement arrangements are not obstructed or invalidated by dominating disturbances from the laboratory d.c. power source. Appropriate EMI filters can be used to decouple the EUT from the d.c. power source. But be aware not to apply too heavy additional common mode capacitive loading to the EUT. Further guidance on suitable decoupling of the laboratory d.c. power source from the measuring arrangement can be found in Annex K.

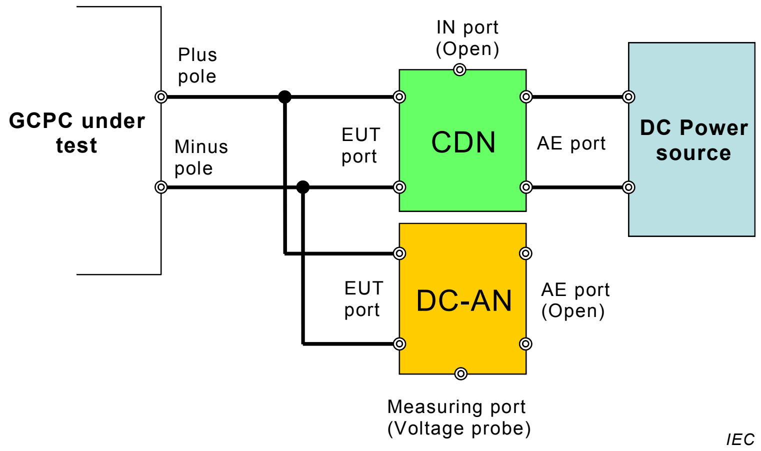


Figure 7 – Typical arrangement for measurement of conducted disturbances at LV d.c. power ports with the DC-AN used as termination and voltage probe

8.2.2.2.3.2 Measurement of the common mode (CM) disturbance voltage

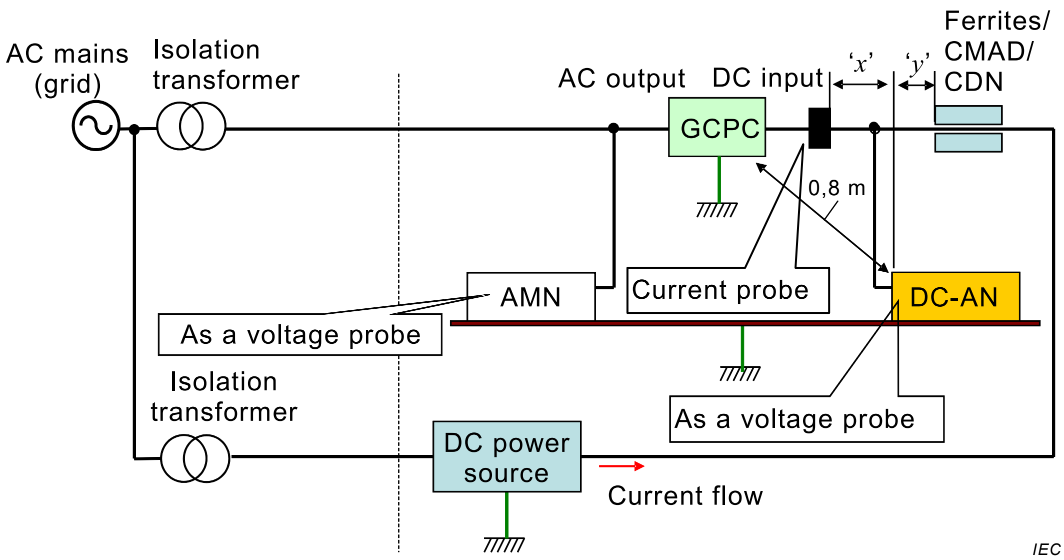
Measurements of the disturbance voltage at the d.c. power port shall be carried out with the DC-AN used as voltage probe, see Figure 7, 8 and 9.

With the DC-AN, the common mode disturbance voltage at the d.c. power port of the power converter shall be measured.

8.2.2.2.3.3 Measurement of the common mode (CM) disturbance current

The common mode disturbance current at the d.c. power cable leading to the laboratory d.c. power source shall be measured using a current probe according to CISPR 16-1-2.

Care shall be taken in order not to alter the termination conditions of the EUT when performing measurements with the current probe. The current probe shall be located a maximum of 30 cm away from the DC-AN. The current probe shall also be in place when performing measurements of the CM disturbance voltage. A suitable measurement arrangement is shown in Figure 8 and 9.



NOTE 'x' and 'y' denote the spacing between the current probe and the DC-AN, and the DC-AN and the ferrite tube(s) / CMAD / CDN, respectively. Spacing x is ≤ 0,3 m and y is 0,1 m.

Figure 8 – Typical arrangement for measurement of conducted disturbances at LV d.c. power ports with the DC-AN used as voltage probe and with a current probe – 2D diagram

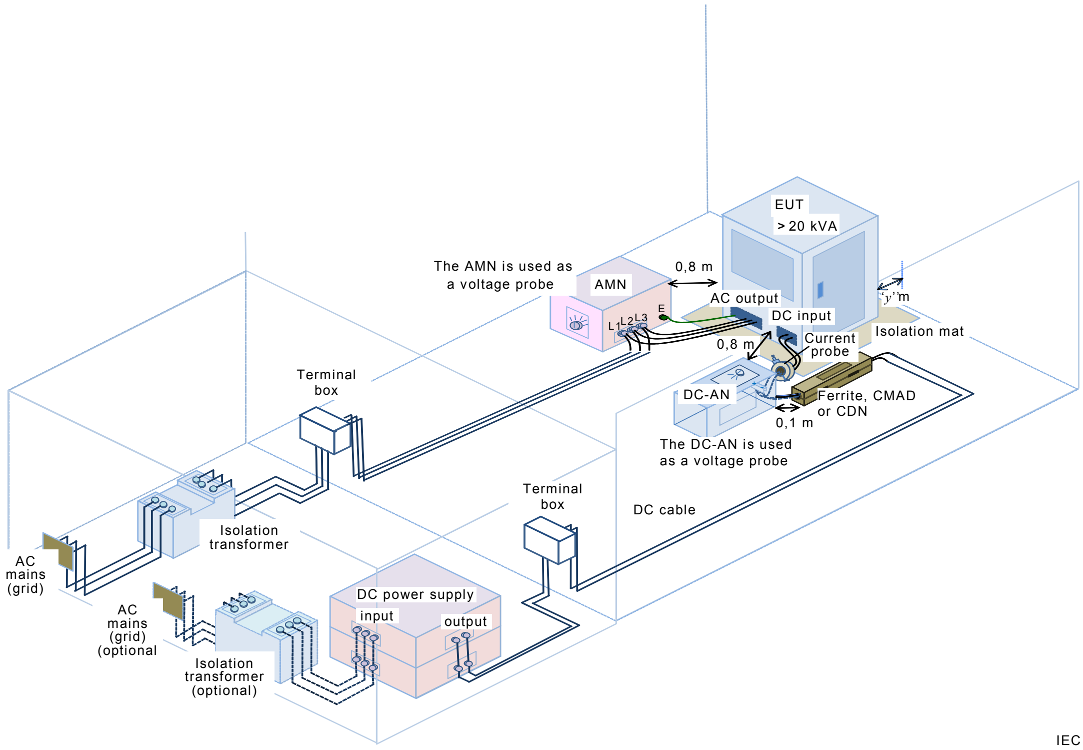


Figure 9 – Typical arrangement for measurement of conducted disturbances at LV d.c. power ports with a DC-AN used as voltage probe and with a current probe – 3D diagram

8.2.2.2.3.4 Compliance criteria

For measurements according to Figure 8, compliance with the limits shall be verified for the measured common mode disturbance voltage and the measured common mode disturbance current. The EUT meets the requirements of CISPR 11 if it can be shown that it meets both the limits of the disturbance voltage and the disturbance current specified in Table 3.

8.2.3 Handheld equipment which are normally operated without an earth connection

For this equipment additional measurements shall be made using the artificial hand described in 7.3.5.

The artificial hand shall be applied only on handles and grips and those parts of the appliance specified as such by the manufacturer. Failing the manufacturer's specification the artificial hand shall be applied in the following way.

The general principle in applying the artificial hand is that the metal foil shall be wrapped around all handles (one artificial hand per handle), both fixed and detachable, supplied with the equipment.

Metalwork which is covered with paint or lacquer is considered as exposed metalwork and shall be directly connected to the terminal M of the RC element.

When the casing of the equipment is entirely of metal, no metal foil is needed, but the terminal M of the RC element shall be connected directly to the body of the equipment.

When the casing of the equipment is of insulating material, a metal foil shall be wrapped around the handles.

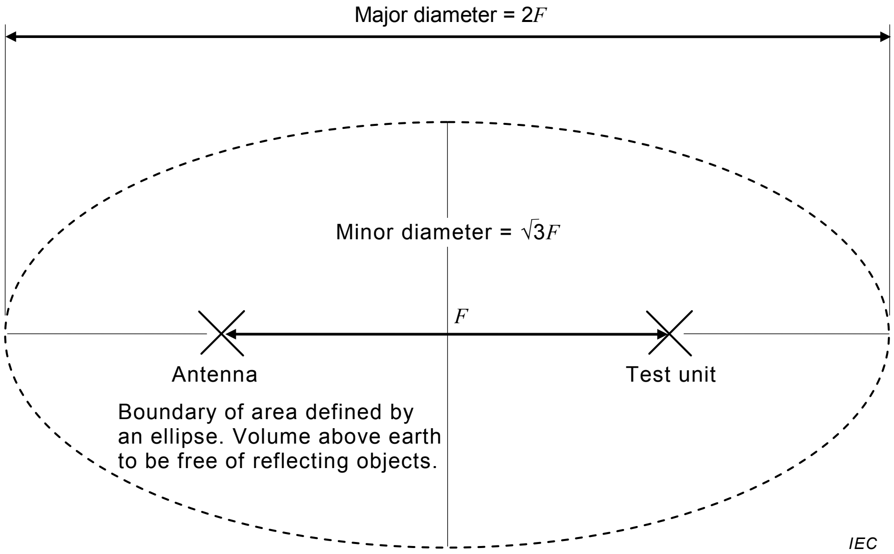
When the casing of the equipment is partly metal and partly insulating materials, and has insulating handles, a metal foil shall be wrapped around the handles.

8.3 Radiation test site for 9 kHz to 1 GHz

8.3.1 General

The radiation test site shall be flat, free of overhead wires and nearby reflecting structures, sufficiently large to permit adequate separation between the antenna, test unit and reflecting structures.

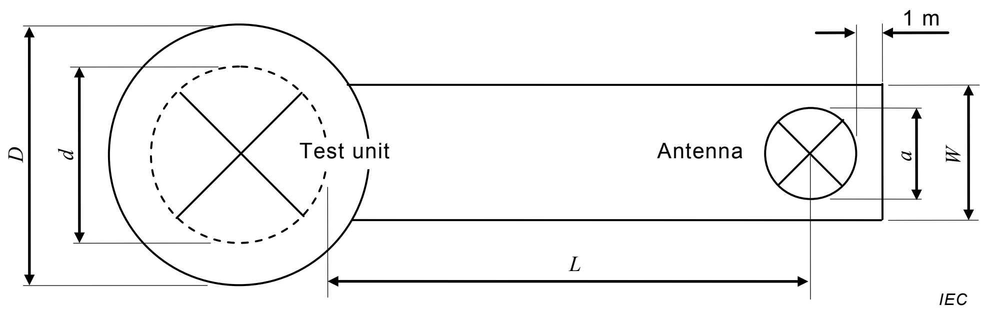
A radiation test site which meets the criteria is within the perimeter of an ellipse having a major axis equal to twice the distance between the foci and a minor axis equal to the square root of three times of this distance. The equipment under test and the measuring equipment are placed at each of the foci respectively. The path length of any ray reflected from an object on the perimeter of this radiation test site will be twice the length of the direct path length between the foci. This radiation test site is depicted in Figure 10.



NOTE For the values of F (measuring distance) see Clause 6.

Figure 10 – Test site

For the 10 m test site, the natural ground plane shall be augmented with a ground plane of metal which shall extend at least 1 m beyond the boundary of the equipment under test at one end and at least 1 m beyond the measurement antenna and its supporting structure at the other end (see Figure 11). The ground plane shall have no voids or gaps other than any perforations which do not exceed 0,1 λ at 1 GHz (about 30 mm).



D = $(d + 2)$ m, where d is the maximum test unit dimension

W = $(a + 1)$ m, where a is the maximum dimension of the antenna

L = measuring distance in metres

Figure 11 – Minimum size of metal ground plane

8.3.2 Validation of the radiation test site (9 kHz to 1 GHz)

Test sites shall be validated according to CISPR 16-1-4 in the frequency ranges where the standard defines requirements.

8.3.3 Disposition of equipment under test (9 kHz to 1 GHz)

For the EUT's earthing and grounding conditions as well as connection to the laboratory's electricity supply network see 7.5.3.1 or 7.5.3.2.

If it is possible to do so, the equipment under test shall be placed on a turntable. The separation between the equipment under test and the measuring antenna shall be the horizontal distance between the reference point of the measuring antenna and the nearest part of the boundary of the equipment under test in one rotation.

8.3.4 Radiation measurements (9 kHz to 1 GHz)

The separation distance between the antenna and the equipment under test shall be as specified in Clause 6. If the field strength measurement at a certain frequency cannot be made at the specified distances because of high ambient noise levels (see 7.2), measurements at this frequency may be made at a closer distance but not less than 3 m. When this is done, the test report shall record the distance actually used and the circumstances of the measurement.

For equipment under test located on a turntable, the turntable shall be rotated fully with a measurement antenna oriented for both horizontal and vertical polarization. The highest recorded level of the electromagnetic radiation disturbance at each frequency shall be recorded.

For equipment under test not located on a turntable the measurement antenna shall be positioned at various points in azimuth for both horizontal and vertical polarization. Care shall be taken that measurements be taken in the directions of maximum radiation and the highest level at each frequency be recorded.

NOTE At each azimuthal position of the measurement antenna the radiation test site requirements specified in 8.3.1 are met.

8.4 Alternative radiation test sites for the frequency range 30 MHz to 1 GHz

Measurements may be performed on radiation test sites which do not have the physical characteristics described in 8.3. Evidence shall be obtained to show that such alternative sites will yield valid results. An alternative radiation test site in the frequency range 30 MHz to 1 GHz is acceptable if the horizontal and vertical site attenuation measurements made as per 5.2.6 of CISPR 16-1-4:2010/AMD 1:2012 are within ± 4 dB of the theoretical site attenuation as given in Tables 1 or 2 of CISPR 16-1-4:2010/AMD 1:2012.

Alternative radiation test sites shall allow for, and be validated for, the measurement distance in the frequency range 30 MHz to 1 GHz specified elsewhere in Clause 6 and/or Clause 8 of this standard.

9 Radiation measurements: 1 GHz to 18 GHz

9.1 Test arrangement

The equipment under test shall be placed on a turntable at a suitable height. Power at the normal voltage shall be supplied. For the EUT's earthing and grounding conditions as well as connection to the laboratory's electricity supply network see 7.5.3.

9.2 Receiving antenna

The measurements shall be made with a directive antenna of small aperture capable of making separate measurements of the vertical and horizontal components of the radiated field. The height above the ground of the centre line of the antenna shall be the same as the height of the approximate radiation centre of the equipment under test. The distance between the receiving antenna and the EUT shall be 3 m.

9.3 Validation and calibration of test site

Test sites shall be validated according to CISPR 16-1-4.

9.4 Measuring procedure

9.4.1 General

The measurements shall take place in free-space conditions, i.e. the reflections on the ground shall not influence the measurements, see CISPR 16-1-4.

The general measuring procedure above 1 GHz specified in CISPR 16-2-3 should be consulted for guidance. Measurements shall be made with the antenna in both horizontal and subsequently vertical polarization. In both cases, the turntable with the equipment under test shall be rotated. It shall be ascertained that, when the equipment under test is switched off, the level of background noise is at least 10 dB below the reference limit, since otherwise the reading may be significantly affected.

A flow chart showing the measurement procedure is shown in Figure 12.

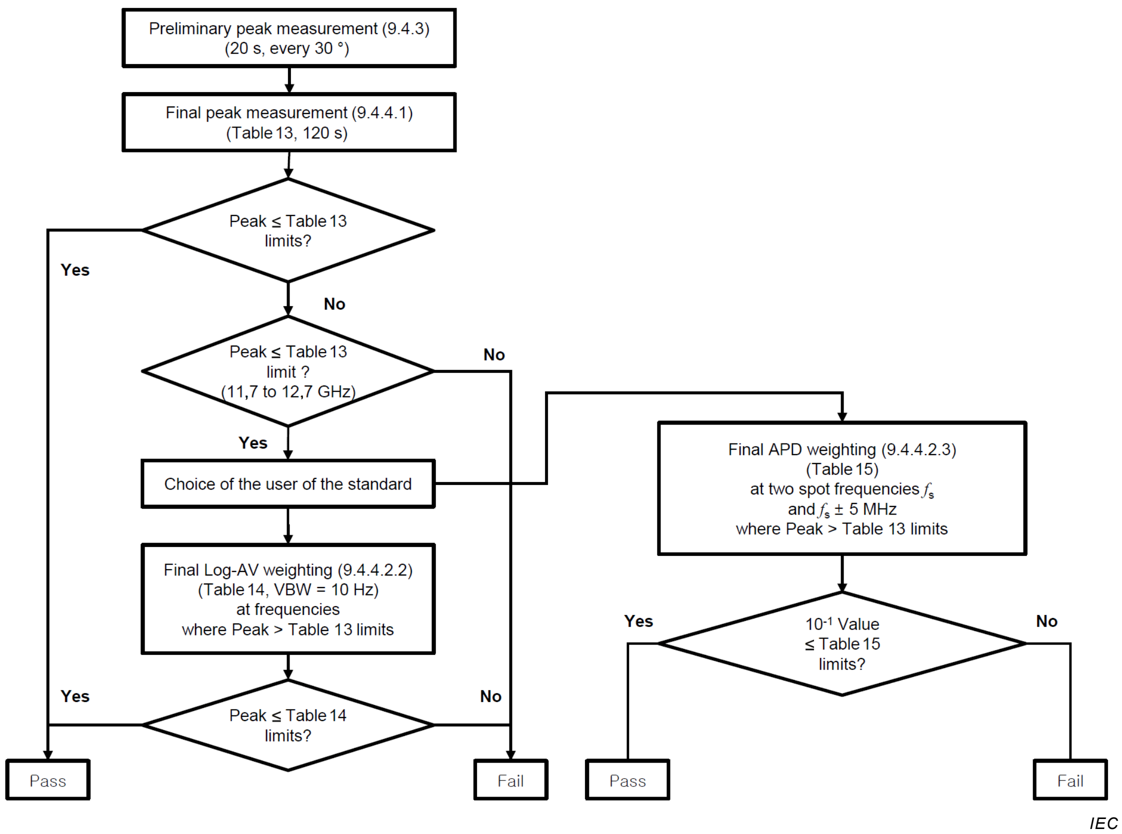


Figure 12 – Decision tree for the measurement of emissions from 1 GHz to 18 GHz of group 2 equipment operating at frequencies above 400 MHz

9.4.2 Operating conditions of the EUT

For microwave ovens, a warm-up period of at least 5 min shall be performed before the measurement.

For all measurements the starting phase of the EUT (a few seconds) is to be ignored.

During the measurements, the microwave oven under test is operated at maximum microwave power setting.

Some microwave ovens automatically turn to an intermittent operation mode if operated for a long time at their highest microwave power setting. In such cases the measurement shall be stopped for a while to allow cooling down until the microwave oven is able to operate at its max power setting without intermittence.

During the measurement, the water load should be exchanged to cold water before it starts to boil. For load conditions of microwave ovens during the measurements see also 7.6.5.

9.4.3 Preliminary measurement

The preliminary measurement comprises of a series of measurements with the peak detector. Peak measurements in the frequency range above 1 GHz (see Table 13) shall be the result of a maximum hold measurement with the spectrum analyzer. The purpose of the preliminary measurement is to identify the position (azimuth) of the EUT in relation to the measuring antenna which results in maximum emissions for each frequency identified.

To find the direction of the maximum emission, peak measurements in the range above 1 GHz shall be made with the azimuth of the EUT varying every 30° (starting position perpendicular to the front surface plane of the EUT, e.g. in a position perpendicular to the front door, in case of microwave ovens). At each of these 12 positions, a measurement in maximum-hold mode shall be made for a period of at least 20 s. Then, at the azimuth position of the EUT where the maximum emission occurred, the final measurement shall be performed.

9.4.4 Final measurement

9.4.4.1 Peak measurement

Peak measurements shall be performed over the whole frequency range 1 GHz to 2,4 GHz and 2,5 GHz to 18 GHz with the EUT positioned as identified during the preliminary measurement. At this azimuth position, a maximum hold measurement for a period of at least 2 min shall be made for both polarizations, i.e. with the antenna oriented successively in horizontal and in vertical polarization.

The obtained measurement result(s) shall be compared to the peak limit (see Table 13).

If the EUT passes the peak measurement, then the final test result is PASS, see Figure 12.

If the EUT does not pass the peak measurement in the satellite radio broadcasting frequency range 11,7 GHz to 12,7 GHz, then the final test result is FAIL, see Figure 12.

9.4.4.2 Weighted measurement

9.4.4.2.1 General

In cases where readings obtained during the peak measurement in the ranges 1 GHz to 11,7 GHz and 12,7 GHz to 18 GHz exceed the limits specified in Table 13 an additional series of measurements with a weighting function shall be performed.

For demonstration of the fluctuating nature of a disturbance, two alternative methods for weighted measurements are available, see also decision tree in Figure 12.

In any situation where it is necessary to re-test the equipment, the measuring method originally chosen shall be used in order to ensure consistency of the results.

9.4.4.2.2 Log-AV weighting according to Table 14

Weighted measurements with the Log-AV method (see Table 14) shall be performed at the azimuth position of the EUT where the maximum peak emission occurred during the preliminary measurement. A minimum of 5 consecutive sweeps in max-hold mode shall be performed.

These weighted measurements shall be performed with the spectrum analyzer in logarithmic display mode (using the logarithmic amplifier, not a mathematical unit conversion of the displayed values).

NOTE A video bandwidth of 10 Hz together with logarithmic amplification provides a level closer to the average level of the measured signal in logarithmic values. This result is lower than the average level that would be obtained in linear mode.

In preparation of the final measurement, the whole frequency range shall be divided into 7 sub-ranges from 1 GHz to 18 GHz according to Table 18.

For every sub-range where the EUT did not meet the limits of Table 13 identify the frequency of the highest emission level from the peak measurements. These frequencies are the centre frequencies to be used for the series of weighted measurements.

Table 18 – Frequency sub-ranges to be used for weighted measurements

Harmonics of 2,45 GHz, Order no.	**Frequency sub-ranges** GHz
Not defined	1,005 to 2,395
2	2,505 to 6,125 [a]
3	6,125 to 8,575
4	8,575 to 11,025
5	11,025 to 13,475
6	13,475 to 15,925
7	15,925 to 17,995

[a] Measurements in the ISM band 5,720 GHz to 5,880 GHz are excluded, see Table 1.

Measurements with the Log-AV weighting function shall be performed in the sub-ranges where the EUT did not meet the limits of Table 13 around the centre frequencies identified in the previous step, within a frequency span of 10 MHz.

Compare the measurement results to the limits of Table 14.

If the EUT passes the measurement with the Log-AV weighting function (Table 14), then the final test result is PASS, see Figure 12.

9.4.4.2.3 APD weighting according to Table 15

As an alternative to 9.4.4.2.2, an APD measurement for a period of 30 s shall be performed at the azimuth of the EUT and the polarization of the antenna where the maximum emission was found during the preliminary peak measurements. Measurements shall be made at the following 6 frequencies (see Figure 12);

f_{s1}, f_{s2},
f_{s1} + 5 MHz, f_{s2} + 5 MHz,
f_{s1} – 5 MHz, f_{s2} – 5 MHz,

where f_{s1} is the frequency with the highest peak emission in the 1 005 MHz to 2 395 MHz range and f_{s2} is the frequency with the highest peak emission in the 2 505 MHz to 17 995 MHz range (but outside the band 5 720 MHz to 5 880 MHz).

Compare the measurement results to the limits of Table 15.

If the EUT passes the measurement with the APD weighting function (Table 15), then the final test result is PASS, see Figure 12.

10 Measurement *in situ*

For equipment which is not tested on a radiation test site, measurements shall be made after the equipment has been installed on the user's premises. Measurements shall be made from the exterior wall outside the building in which the equipment is situated at the distance specified in 6.4.

Measurements *in situ* at the place of operation of the equipment to be assessed shall be performed and documented in accordance with 7.7 of CISPR 16-2-3:2010. Further advice for *in situ* measurements is also found in CISPR TR 16-2-5 [2] [3].

The number of measurements made in azimuth shall be as great as reasonably practical, but there shall be at least four measurements in orthogonal directions, and measurements in the direction of any existing radio systems which may be adversely affected.

For the larger commercial microwave ovens it is necessary to ensure that the measurement results are not affected by near field effects. CISPR 16-2-3 should be consulted for guidance.

11 Safety precautions for emission measurements on ISM RF equipment

ISM RF equipment is inherently capable of emitting levels of electromagnetic radiation that are hazardous to human beings. Before testing for electromagnetic radiation disturbance, the ISM RF equipment should be checked with a suitable radiation monitor.

12 Measurement uncertainty

Determining compliance with the limits in this standard shall be based on the results of the compliance measurements taking into account the considerations on measurement instrumentation uncertainty.

Where guidance for the calculation of the instrumentation uncertainty of a measurement is specified in CISPR 16-4-2 this shall be followed, and for these measurements the determination of compliance with the limits in this standard shall take into consideration the measurement instrumentation uncertainty in accordance with CISPR 16-4-2. Calculations to determine the measurement result and any adjustment of the test result required when the test laboratory uncertainty is larger than the value for U_{CISPR} given in CISPR 16-4-2 shall also be included in the test report.

For *in situ* measurements, the contribution of uncertainty due to the site itself is excluded from the uncertainty calculation.

NOTE When performing measurements at distances less than 10 m, higher measurement uncertainties may have to be taken into account.

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3 Figures in square brackets refer to the Bibliography.

Annex A
(informative)

Examples of equipment classification

Many types of equipment in the scope of this standard contain two or more types of interference sources, for example an induction heater might incorporate semiconductor rectifiers in addition to its heating coil. For testing purposes the equipment is to be defined in terms of the purpose for which it was designed. For example, the induction heater incorporating semiconductor rectifiers is to be tested as an induction heater (with all disturbances meeting the prescribed limits whatever the source of disturbance) and is not to be tested as if it were a semiconductor power supply.

The standard gives general definitions of group 1 and group 2 equipment and for official purposes the group to which a particular piece of apparatus belongs shall be identified from these definitions. It will, however, be helpful to users of the standard to have a comprehensive list of types of apparatus which have been identified as belonging to a particular group. This will also help in developing the specification where variations in test procedures may be found by experience to be necessary in dealing with specific types of apparatus.

The following lists of group 1 and group 2 equipment are not exhaustive.

Group 1

Group 1 equipment: group 1 contains all equipment in the scope of this standard which is not classified as group 2 equipment.

General: Laboratory equipment
Medical electrical equipment
Scientific equipment
Semiconductor converters
Industrial electroheating equipment with operating frequencies less than
or equal to 9 kHz
Machine tools
Industrial process measurement and control equipment
Semiconductor manufacturing equipment

Detailed: Signal generators, measuring receivers, frequency counters, flow meters, spectrum analysers, weighing machines, chemical analysis machines, electronic microscopes, switched mode power supplies and semiconductor converters (when not incorporated in an equipment), semiconductor rectifiers/inverters, grid connected power converters (GCPC), resistance heating equipment with built-in semiconductor AC power controllers, arc furnaces and metal melting ovens, plasma and glow discharge heaters, X-ray diagnostic equipment, computerised tomography equipment, patient monitoring equipment, ultrasound diagnostic and therapy equipment, ultrasound washing machines, regulating controls and equipment with regulating controls incorporating semiconductor devices with a rated input current in excess of 25 A per phase

Group 2

Group 2 equipment: group 2 contains all ISM RF equipment in which radio-frequency energy in the frequency range 9 kHz to 400 GHz is intentionally generated and used or only used locally, in the form of electromagnetic radiation, inductive and/or capacitive coupling, for the treatment of material, for inspection/analysis purposes, or for transfer of electromagnetic energy.

General: Microwave-powered UV irradiating apparatus
Microwave lighting apparatus

Industrial induction heating equipment operating at frequencies above 9 kHz

Inductive power transfer / charging equipment [a]

Dielectric heating equipment

Industrial microwave heating equipment

Microwave ovens

Medical electrical equipment

Electric welding equipment

Electro-discharge machining (EDM) equipment

Demonstration models for education and training

[a] Inductive or capacitive power transfer apparatus normally subject to CISPR 11, but forming part of equipment subject to other CISPR standards is excluded from the scope of CISPR 11.

Detailed: Metal melting, billet heating, component heating, soldering and brazing, arc welding, arc stud welding, resistance welding, spot welding, tube welding, industrial laser oscillator exited by high-frequency discharge, wood gluing, plastic welding, plastic preheating, food processing, biscuit baking, food thawing, paper drying, textile treatment, adhesive curing, material preheating, short-wave diathermy equipment, microwave therapy equipment, magnetic resonance imaging (MRI), medical HF sterilizers, high-frequency (HF) surgical equipment, crystal zone refining, demonstration models of high-voltage Tesla transformers, belt generators, etc.

Annex B
(informative)

Precautions to be taken in the use of a spectrum analyzer (see 7.3.1)

Most spectrum analyzers have no radio-frequency selectivity: that is, the input signal is fed directly to a broadband mixer, where it is heterodyned to a suitable intermediate frequency. Microwave spectrum analyzers are obtainable with tracking radio-frequency pre-selectors which automatically follow the frequency being scanned by the receiver. These analyzers overcome to a considerable degree the disadvantages of attempting to measure the amplitudes of harmonic and spurious emissions with an instrument which can generate such components in its input circuits.

In order to protect the input circuits of the spectrum analyzer from damage when measuring weak disturbance signals in the presence of a strong signal, a filter should be provided in the input to give at least 30 dB of attenuation at the frequency of the strong signal. A number of such filters may be required to deal with different operating frequencies.

Many microwave spectrum analyzers employ harmonics of the local oscillator to cover various portions of the tuning range. Without radio-frequency pre-selection, such analyzers may display spurious and harmonic signals. It thus becomes difficult to determine whether a displayed signal is actually at the indicated frequency, or is generated within the instrument.

Many ovens, medical diathermy equipment and other microwave ISM RF equipment receive their input power from rectified a.c. but unfiltered energy sources. Consequently, their emissions are simultaneously modulated in amplitude and frequency. Additional AM and FM are caused by the movement of stirring devices used in ovens.

These emissions have spectral line components as close together as 1 Hz (due to modulation by the oven stirring device), and 50 Hz or 60 Hz (due to the modulation at mains frequency). Considering that the carrier frequency is generally rather unstable, distinguishing these spectral line components is not feasible. Rather, it is the practice to display the envelope of the true spectrum by employing an analyzer bandwidth which is larger than the frequency interval between spectral components (but as a rule small in relation to the width of the spectral envelope).

When the analyzer bandwidth is wide enough to contain a number of adjacent spectral lines, the indicated peak value increases with bandwidth up to the point where the analyzer bandwidth is comparable to the width of the spectrum of the signal. It is essential, therefore, to obtain agreement to use a specified bandwidth in order to compare the amplitudes displayed by different analyzers when measuring emissions typical of present heating and therapeutic devices.

It has been indicated that many oven emissions are modulated at a rate as low as 1 Hz. It has been observed that the displayed spectral envelopes of such emissions are irregular, appearing to vary from scan to scan, unless the number of scans per second is low compared with this lowest frequency component of the modulation.

A suitable rate for investigation of the emission may require 10 s or more to accomplish one scan. Such low scanning rates are not suitable for visual observation unless suitable storage is employed, such as that provided by a storage-type cathode ray tube, a photograph, or a chart recording device. Some attempts have been made to increase the useful scanning frequency by removing or stopping the stirring devices in the oven. However, this may be considered unsatisfactory because the amplitude, frequency and shape of the spectrum are found to vary with the position of the stirrers.

Annex C
(normative)

Measurement of electromagnetic radiation disturbance in the presence of signals from radio transmitters

For equipment under test having a stable operating frequency so that reading of the CISPR quasi-peak measuring receiver does not vary more than ±0,5 dB during measurement, the electric field strength of the electromagnetic radiation disturbance can be calculated sufficiently accurately from the expression:

$$E_g^{1,1} = E_t^{1,1} - E_s^{1,1}$$

where

E_g is the electromagnetic radiation disturbance (μV/m);

E_t is the measured value of electric field strength (μV/m);

E_s is the electric field strength of the radio transmitter signal (μV/m).

The formula has been found to be valid when unwanted signals are from AM or FM sound and television transmitters having a total amplitude up to twice the amplitude of the electromagnetic radiation disturbance which is to be measured.

It is advisable to restrict the use of the formula to cases where it is not possible to avoid the disturbing effect of radio transmitters. If the frequency of the electromagnetic radiation disturbance is unstable then a panoramic receiver or spectrum analyzer should be used, and the formula is not applicable.

Annex D
(informative)

Propagation of interference from industrial radio-frequency equipment at frequencies between 30 MHz and 300 MHz

For industrial radio-frequency equipment which is situated on or near ground level, the attenuation of the field with distance from source, at a height of between 1 m and 4 m above ground, depends on the ground and on the nature of the terrain. A model for electric field propagation above plane-earth in the region from 1 m to 10 km from the source is described in [15][4].

Although the influence of the nature of the ground, and of the obstacles on it, on the actual attenuation of the electromagnetic wave increases with frequency, an average attenuation coefficient can be taken for the frequency range 30 MHz to 300 MHz.

As ground irregularity and clutter increase, the electromagnetic fields will be reduced because of shadowing, absorption (including attenuation caused by buildings and vegetation), scattering, divergence and defocusing of the diffracted waves [16]. The attenuation can then be described only on a statistical basis. For distances from the source greater than 30 m, the expected or median field strength at a defined height varies as $1/D^n$ where D is the distance from the source, and n varies from about 1,3 for open country areas to about 2,8 for heavily built-up urban areas. It seems from the different measurements for all kinds of terrain that an average value of $n = 2,2$ can be used for approximate estimations. Large deviations of measured values of field strengths from those predicted from the average field strength/distance law occur, with standard deviations of up to about 10 dB in an approximately log-normal distribution. The polarization of the field cannot be predicted. These results are in agreement with measurements in a number of countries.

The screening effect of buildings on the radiation is a very variable quantity, depending on the material of the buildings, the wall thickness and the amount of window space. For solid walls without windows, the attenuation depends on their thickness relative to the wavelength of the radiation and an increase in attenuation with frequency may be expected.

Generally, however, it is considered unwise to expect buildings to give protection of much more than 10 dB.

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[4] Figures in square brackets refer to the Bibliography.

Annex E
(informative)

Recommendations of CISPR for protection of certain radio services in particular areas

E.1 General

The ITU develops usage provisions aiming at the efficient use of the radio frequency spectrum and local control of radiated RF disturbances at the place of operation of individual ISM RF applications. The respective provisions of the ITU relating to usual residential and/or industrial environments are recognised by CISPR and incorporated into the main body of this International Standard. Apart from these provisions, additional ITU provisions may apply for the *operation and use* of *individual* ISM RF applications in particular environments, i.e. in "particular areas", which are not addressed in the main body of this standard. The CISPR regards these ITU provisions and their national derivatives as recommendations since they may only apply to *individual* ISM RF applications used in *particular areas* under *in situ* conditions.

E.2 Recommendations for protection of safety-related radio services

ISM RF equipment should be designed to avoid fundamental operations or radiation of high-level spurious and harmonic signals in bands used for safety-related radio services. A list of these bands is provided in Annex F.

NOTE For the protection of specific safety-related radio services, in particular areas, an individual installation can be required to meet the limits specified in Table E.1.

Table E.1 – Limits for electromagnetic radiation disturbances for *in situ* measurements to protect specific safety-related radio services in particular areas

Frequency range MHz	Limits		Measuring distance D from the outer face of the exterior wall outside the building in which the equipment is situated
	Electric field Quasi-peak dB(μV/m)	Magnetic field Quasi-peak dB(μA/m)	Distance D m
0,283 5 – 0,526 5	–	13,5	30
74,6 – 75,4	30	–	10
108 – 137	30	–	10
242,95 – 243,05	37	–	10
328,6 – 335,4	37	–	10
960 – 1 215	37	–	10

E.3 Recommendations for protection of specific sensitive radio services

For the protection of specific sensitive radio services, in particular areas, it is recommended to avoid fundamental operations or the radiation of high level harmonic signals in the bands. Some examples of these bands are listed for information in Annex G.

NOTE For the protection of specific sensitive services, in particular areas, national authorities can request additional suppression measures or designated separation zones for cases where harmful interference may occur.

Annex F
(informative)

Frequency bands allocated for safety-related radio services

Frequency MHz	**Allocation/use**
0,010 – 0,014	Radionavigation (Omega on board ships and aircraft only)
0,090 – 0,11	Radionavigation (LORAN-C and DECCA)
0,283 5 – 0,526 5	Aeronautical radionavigation (non-directional beacons)
0,489 – 0,519	Maritime safety information (coastal areas and shipboard only)
1,82 – 1,88	Radionavigation (LORAN-A region 3 only, coastal areas and on board ships only)
2,173 5 – 2,190 5	Mobile distress frequency
2,090 55 – 2,091 05	Emergency position indicating radio beacon (EPIRB)
3,021 5 – 3,027 5	Aeronautic mobile (search and rescue operations)
4,122 – 4,210 5	Mobile distress frequency
5,678 5 – 5,684 5	Aeronautic mobile (search and rescue operations)
6,212 – 6,314	Mobile distress frequency
8,288 – 8,417	Mobile distress frequency
12,287 – 12,579 5	Mobile distress frequency
16,417 – 16,807	Mobile distress frequency
19,68 – 19,681	Maritime safety information (coastal areas and shipboard only)
22,375 5 – 22,376 5	Maritime safety information (coastal areas and shipboard only)
26,1 – 26,101	Maritime safety information (coastal areas and shipboard only)
74,6 – 75,4	Aeronautical radionavigation (marker beacons)
108 – 137	Aeronautical radionavigation (108 MHz to 118 MHz VOR, 121,4 MHz to 123,5 MHz distress frequency SARSAT uplink, 118 MHz to 137 MHz air traffic control)
156,2 – 156,837 5	Maritime mobile distress frequency
242,9 – 243,1	Search and rescue (SARSAT uplink)
328,6 – 335,4	Aeronautical radionavigation (ILS glideslope indicator)
399,9 – 400,05	Radionavigation satellite
406 – 406,1	Search and rescue (emergency position-indicating radio beacon (EPIRB), SARSAT uplink)
960 – 1 238	Aeronautical radionavigation (TACAN), air traffic control beacons
1 300 – 1 350	Aeronautical radionavigation (long range air search radars)
1 544 – 1 545	Distress frequency-SARSAT downlink (1 530 MHz to 1 544 MHz mobile satellite downlink may be pre-empted for distress purposes)
1 545 – 1 559	Aeronautical mobile satellite (R)
1 559 – 1 610	Aeronautical radionavigation (GPS)
1 610 – 1 625,5	Aeronautical radionavigation (radio altimeters)
1 645,5 – 1 646,5	Distress frequency-uplink (1 626,5 MHz to 1 645,5 MHz mobile satellite uplink may be pre-empted for distress purposes)
1 646,5 – 1 660,5	Aeronautical mobile satellite (R)
2 700 – 2 900	Aeronautical radionavigation (terminal air traffic control radars)
2 900 – 3 100	Aeronautical radionavigation (radar beacons – coastal areas and shipboard only)
4 200 – 4 400	Aeronautical radionavigation (altimeters)
5 000 – 5 250	Aeronautical radionavigation (microwave landing systems)
5 350 – 5 460	Aeronautical radionavigation (airborne radars and beacons)
5 600 – 5 650	Terminal Doppler weather radar – wind shear
9 000 – 9 200	Aeronautical radionavigation (precision approach radars)
9 200 – 9 500	Radar transponders for maritime search and rescue. Maritime radar beacons and radionavigation radars. Airborne weather and ground mapping radar for airborne radionavigation, particularly under poor visibility conditions
13 250 – 13 400	Aeronautical radionavigation (Doppler navigation radars)

Annex G
(informative)

Frequency bands allocated for sensitive radio services

Frequency MHz	Allocation/Use
0,135 7 − 0,137 8	Amateur Radio Service
0,472 − 0,479	Amateur Radio Service
1,80 – 2,00	Amateur Radio Service
3,50 – 4,00	Amateur Radio Service
5,25 – 5,45	Amateur Radio Service
7,00 – 7,30	Amateur Radio Service
10,100 − 10,150	Amateur Radio Service
13,36 − 13,41	Radio astronomy
14,00 – 14,35	Amateur Radio Service
18,068 – 18,168	Amateur Radio Service
21,00 – 21,45	Amateur Radio Service
24,89 – 24,99	Amateur Radio Service
25,5 − 25,67	Radio astronomy
28,00 – 29,7	Amateur Radio Service
29,3 − 29,55	Satellite downlink (Amateur Radio Satellite Service)
37,5 − 38,25	Radio astronomy
50 – 54	Amateur Radio Service
70,0 – 70,5	Amateur Radio Service
73 − 74,6	Radio astronomy
137 − 138	Satellite downlink
144 – 146	Amateur Radio Service
145,8 − 146	Satellite downlink (Amateur Radio Satellite Service)
149,9 − 150,05	Radionavigation satellite downlink
240 − 285	Satellite downlink
322 − 328,6	Radio astronomy
400,05 − 400,15	Standard frequency and time signal
400,15 − 402	Satellite downlink
402 − 406	Satellite uplink 402,5 MHz
406,1 − 410	Radio astronomy
430 − 440	Amateur Radio Service
435 − 438	Satellite downlink (Amateur Radio Satellite Service)
608 − 614	Radio astronomy
1 215 − 1 240	Satellite downlink
1 240 − 1 300	Amateur Radio Service
1 260 − 1 270	Satellite uplink
1 350 − 1 400	Spectral line observation of neutral hydrogen (radio astronomy)
1 400 − 1 427	Radio astronomy
1 435 − 1 530	Aeronautical flight test telemetry
1 530 − 1 559	Satellite downlink
1 559 − 1 610	Satellite downlink
1 610,6 − 1 613,8	Spectral line observations of OH radical (radio astronomy)
1 660 − 1 710	1 660 MHz to 1 668,4 MHz: Radio astronomy 1 668,4 MHz to 1 670 MHz: Radio astronomy and radiosonde 1 670 MHz to 1 710 MHz: Satellite downlink and radiosonde
1 718,8 − 1 722,2	Radio astronomy

Frequency bands allocated for sensitive radio services (*list continued)*

Frequency MHz	**Allocation/Use**
2 200 − 2 300	Satellite downlink
2 320 − 2 450	Amateur Radio Service
2 310 − 2 390	Aeronautical flight test telemetry
2 655 − 2 900	2 655 MHz to 2 690 MHz: Radio astronomy and satellite downlink
	2 690 MHz to 2 700 MHz: Radio astronomy
3 260 − 3 267	Spectral line observations (radio astronomy)
3 332 − 3 339	Spectral line observations (radio astronomy)
3 345,8 − 3 358	Spectral line observations (radio astronomy)
3 400 − 3 475	Amateur Radio Service
3 400 − 3 410	Satellite downlink
3 600 − 4 200	Satellite downlink
4 500 − 5 250	4 500 MHz to 4 800 MHz: Satellite downlink
	4 800 MHz to 5 000 MHz: Radio astronomy
	5 000 MHz to 5 250 MHz: Aeronautical radionavigation
5 650 − 5 950	Amateur Radio Service
7 250 − 7 750	Satellite downlink
8 025 − 8 500	Satellite downlink
10 000 – 10 500	Amateur Radio Service
104 50 − 10 500	Satellite downlink
10 600 − 12 700	10,6 − 10,7 GHz: Radio astronomy
	10,7 − 12,2 GHz: Satellite downlink
	12,2 – 12,7 GHz: Direct broadcast satellite
14 470 − 14 500	Spectral line observations (radio astronomy)
15 350 − 15 400	Radio astronomy
17 700 − 21 400	Satellite downlink
21 400 − 22 000	Broadcast satellite (Region 1 and Region 2)
22 010 − 23 120	22,01 GHz to 22,5 GHz: Radio astronomy 22,5 GHz to 23,0 GHz: Broadcast satellite (Region 1) (22,81 GHz to 22,86 GHz is also radio astronomy) 23,0 GHz to 23,07 GHz: Fixed/intersatellite/mobile (used to fill in the gap between frequency bands) 23,07 GHz to 23,12 GHz: Radio astronomy
23 600 − 24 000	Radio astronomy
24 000 − 24 500	Amateur Radio Service
31 200 − 31 800	Radio astronomy
36 430 − 36 500	Radio astronomy
38 600 − 40 000	Radio astronomy
above 400 GHz	Numerous bands above 400 GHz are designated for radio astronomy, satellite downlink, etc.

Annex H
(informative)

Statistical assessment of series produced equipment against the requirements of CISPR standards

H.1 Significance of a CISPR limit

A CISPR limit is a limit which is recommended to national authorities for incorporation in national standards, relevant legal regulations and official specifications. It is also recommended that international organizations use these limits. The significance of the limits for *type approved* appliances shall be that on a statistical basis at least 80 % of the mass-produced appliances comply with the limits with at least 80 % confidence.

The assessment of conformity of equipment tested on a test site shall be based on measurement results obtained in accordance with the specifications of Clause 7. For equipment in series production, there shall be 80 % confidence that at least 80 % of manufactured items comply with the limits given (compliance criterion), see CISPR 16-4-3. Statistical assessment procedures providing such a confidence level are specified in H.3.1, H.3.2 and H.3.3.

NOTE When applying another statistical assessment procedure than one of those referred to above or specified in CISPR 16-4-3, the user of this standard can be invited to show evidence that the compliance criterion set out above is also met when applying this other method.

Measurement results obtained for an equipment measured in its place of use and not on a test site shall be regarded as relating to that installation only, and shall not be considered representative of any other installation and so shall not be used for the purpose of a statistical assessment.

H.2 Type tests

As a rule, the positive result of a *type test* on a given appliance according to the respective CISPR standard will be recognized as *approval of the type* if the type test was performed

H.2.1 either on a sample of appliances of the type using one of the statistical methods of evaluation in accordance with H.3,

H.2.2 or, for simplicities sake, on one appliance only. In this case subsequent tests are necessary from time to time on appliances taken at random from the production line.

NOTE Recognition of a *type test* made on only one appliance of series-produced equipment as *type approval* may depend on national or regional regulation. National or regional authorities may rely on different quality assurance systems to be maintained by the manufacturer. Consult respective national or regional regulations.

H.3 Statistical assessment of series produced equipment

H.3.1 Assessment based on a general margin to the limit

The assessment is positive when the measured values from all items of the sample are under the limit L, and the margin to that limit is not smaller than the general margin given in Table H.1 below.

Table H.1 – General margin to the limit for statistical evaluation

Sample size (n)	3	4	5	6
General margin to the limit (dB)	3,8	2,5	1,5	0,7

This method can be used to get a quick final pass-decision. If the conditions are not fulfilled, this does not yet mean that a product is non-compliant. To determine non-compliance, the measured results shall be evaluated by one of the methods in H.3.2. (use of non-central t-distribution) or H.3.3 (use of binomial distribution).

NOTE The newly introduced method in this subclause is based on CISPR 16-4-3.

The values in Table H.1 have been calculated with the following methodology: Compliance is given, when

$$x_{\max} + k_E \, \sigma_{\max} \leq L$$

where

$x_{\max}$ is the highest (worse) measured value of all items in the sample;

k_E is the coefficient from the table below, depending on the sample size;

$\sigma_{\max}$ is a conservative value for the expected maximum standard deviation in a product group, and which is calculated as 2 times the expected standard deviation;

L is the limit specified in this standard.

The quantities x, L and $\sigma_{\max}$ are expressed in logarithmic terms while k_E , as an ordinary factor, is given in absolute numerical value, see table in this NOTE.

Sample size (n)	3	4	5	6
Coefficient k_E	0,63	0,41	0,24	0,12

CISPR 16-4-3 recommends a value $\sigma_{\max}$ = 6,0 dB for both the disturbance voltage and the disturbance power. For radiated disturbances, measured on equipment in the scope of this standard, the same value for $\sigma_{\max}$ has been assumed. The values for the general margin to the limit in Table H.1 above are a simple multiplication of this 6,0 dB with the coefficient k_E. In Table H.1 values are given only for a sample size up to n = 6 because for n = 7 or higher the method given in H.3.3 can be applied, where the binomial distribution without an additional margin is used.

H.3.2 Assessment based on the non-central t-distribution

H.3.2.1 Normal procedure

The measurements shall be performed on a sample of not less than five and not more than 12 pieces of equipment of the type in series production, but if in exceptional circumstances five pieces of equipment are not available a sample of three or four may be used.

NOTE The assessment made on a sample of the measurement results obtained for a sample of size n relates to all identical units and allows for the variations that can be expected to arise due to quantity production techniques.

Compliance is achieved when the following relationship is met:

$$\overline{X} + kS_n \leq L$$

where

$\overline{X}$ is the arithmetic mean value of the disturbance levels of n items of equipment in the sample;

S_n is the standard deviation of the sample where

$$S_n^2 = \frac{1}{n-1} \times \sum \left(X - \overline{X}\right)^2$$

X is the disturbance level of an individual equipment;

L is the permitted limit;

k is the factor derived from tables of the non-central t-distribution which ensures with 80 % confidence that 80 % or more of the production is below the limit. Values of k as a function of n are given in Table H.2.

$\overline{X}$, X and L are expressed logarithmically: dB(μV), dB(μV/m) or dB(pW).

S_n is expressed in logarithmic term, i.e. in dB.

Table H.2 – The non-central *t*-distribution factor *k* as a function of the sample size *n*

n	3	4	5	6	7	8	9	10	11	12
k	2,04	1,69	1,52	1,42	1,35	1,30	1,27	1,24	1,21	1,20

H.3.2.2 Extended procedure

When applying the procedure as in H.3.2.1 a given sample of equipment which causes fluctuating disturbances may fail to meet the compliance criterion. In such cases the extended assessment procedure defined in this clause can be used.

The statistical assessment shall be carried out separately for the following frequency subranges:

Conducted disturbances:
- a) 150 kHz to 500 kHz
- b) 500 kHz to 5 MHz
- c) 5 MHz to 30 MHz

Radiated disturbances below 1 GHz:
- a) 30 MHz to 230 MHz
- b) 230 MHz to 500 MHz
- c) 500 MHz to 1 000 MHz

Radiated disturbances above 1 GHz:
- a) 1,0 GHz to 4,5 GHz
- b) 4,5 GHz to 18 GHz

NOTE For group 2 equipment, there may be no need to fully or continuously cover the frequency subranges defined above, see respective information in 6.3.2.4, Table 13.

Compliance of the sample is judged from the following modified relationship:

$$\overline{X} + kS_n \leq 0$$

The value of k depends on the sample size n and is stated in Table H.2 above.

For determination of compliance, the standard deviation formula as in H.3.2.1 shall be used:

$$S_n^2 = \frac{1}{n-1} \times \sum \left(X - \overline{X} \right)^2$$

where

$\overline{X}$ is the arithmetic mean value of the disturbance levels of n items of equipment in the sample;

X is the margin of the disturbance level of an individual item of equipment to the respective limit. X is to be determined as follows: for each of the defined frequency ranges, the margins between the measured values (readings) and the limit are defined. The resulting margin X is negative where the measured value is below the limit, and positive, where it is higher than the limit. For the n^{th} individual item of the sample, X_n is the value of the margin at the frequency where the margin curve shows its maximum.

NOTE If all measured values are below the limit, X_n is the smallest margin to the limit. If some of the measured values are above the limit, X_n is the largest margin by which the limit is exceeded.

X, $\overline{X}$ and S_n are expressed logarithmically, i. e. in dB.

If all measured values are below the limit and the statistical assessment failed only due to a high standard deviation, it shall be investigated whether this high standard deviation has been unjustifiably caused by a maximum of X_n at the borderline between two frequency subranges. In this case the assessment can be done according to H.3.3.

NOTE The Figure H.1 below illustrates the possible difficulties if a maximum of the measured disturbances occurs near the borderline between two frequency sub-ranges. "U" is the measured disturbance voltage; "f" is the frequency. Here two units with different characteristics out of a sample are shown. For broadband disturbances the value of the maximum as well as the frequency of the maximum can change from unit to unit, differences as between unit 1 and unit 2 in a sample are typical. An average value and standard deviation is calculated for all units (of which two are shown) for each subrange. In this example the calculated standard deviation is much higher for subrange 1 than subrange 2 (e.g. consider how different the values of X_1 and X_2 are at the borderline). Even though the average for subrange 1 is much lower than subrange 2, after taking into consideration the high value of S_n multiplied by the factor out of Table H.2, in rare cases this could lead to the sample set failing the given criteria. Since this is simply a consequence of the way in which the frequency subranges have been defined, no statistically meaningful conclusion can be drawn regarding compliance.

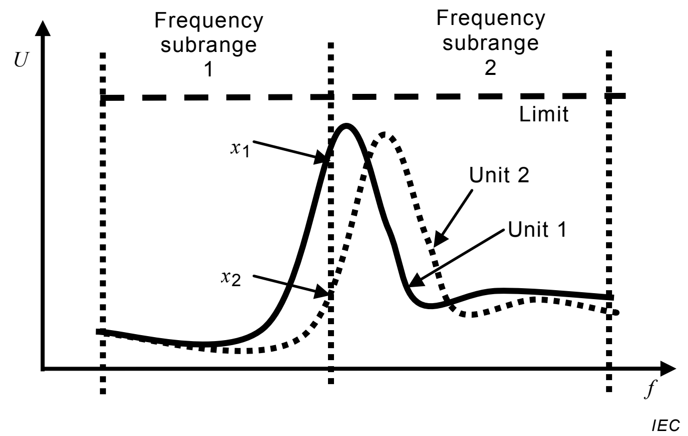


Figure H.1 – An example of possible difficulties

H.3.3 Assessment based on the binomial distribution

Compliance is judged from the condition that the number of appliances with a disturbance level above the appropriate limit may not exceed a number of c in a sample of total size n, see Table H.3.

Table H.3 – Application of the binomial distribution

Sample size (n)	7	14	20	26	32
Number of samples c exceeding the limit L	0	1	2	3	4

H.3.4 Equipment produced on an individual basis

All equipment not produced in series shall be tested on an individual basis. Each individual item of equipment is required to meet the limits when measured by the methods specified.

Annex I
(normative)

Artificial Network (AN) for the assessment of disturbance voltages at d.c. power ports of semiconductor power converters

I.1 General information and purpose

The artificial network for the assessment of disturbance voltages at d.c. power ports (DC-AN) provides a defined common mode (CM) 150 Ω termination impedance for the d.c. power port of the power converter under test during measurements of conducted RF disturbances at standardized test sites. It is constructed to provide, in the intended frequency range from 150 kHz to 30 MHz, well defined termination impedances for symmetric (or differential mode – DM) as well as asymmetric (or common mode – CM) disturbance components. The values of these termination impedances are specified in Clause I.4.

Further, the DC-AN is furnished with a decoupling network (i.e. an LC-filter) such that sufficient decoupling is provided between its EUT port and its AE port, in order to prevent RF disturbances from the laboratory d.c. power source to affect obtained measuring results. Having asymmetric decoupling capacitors with some 100 nF to about 1 μF capacitance only the construction of that filter prevents, in most cases, saturation effects in mitigation filters the power converters may be furnished with and this way provides for valid, reliable and repeatable measurement results.

I.2 Structures for a DC-AN

I.2.1 AN suitable for measurement of unsymmetrical mode (UM) disturbances

Similar to the V-AMN, the AN shall allow for measurement of the unsymmetrical mode disturbance voltage level at a single terminal (or conductor or pole, respectively) of the EUT's d.c. power port under test, relative to laboratory reference ground. An appropriate AN would hence be e.g. a pseudo V-AN, a kind of delta network. For layout and design, the principles set out in CISPR 16-1-2 shall be observed. A circuit diagram of a suitable Delta-network is found in Figure I.1.

NOTE Due to constraints in design of true V-ANs for a certain defined ratio of the DM to CM termination impedance, construction of a pseudo V-AN may require use of a third shunting resistor connecting to the two power terminals of the EUT port of the AN. Such shunting resistors as R_2 in Figure I.1 or R_3 in Figure I.4 do not have any impact on the required DM and CM termination impedances and provide for these termination impedances also during measurement of UM disturbance voltages. For calculation of the termination impedance for UM disturbance voltages the delta-to-star conversion formula for resistor networks can be used. Further, these termination impedances can also be measured directly at the EUT power terminals of the AN in relation to common ground in using an appropriate network analyser. Distinction in V- and Delta-ANs is kept for traditional reasons only. UM disturbance voltages can also easily be measured with Delta-ANs when they are furnished with respective measuring ports.

I.2.2 AN suitable for measurement of common mode (CM) and differential mode (DM) disturbances

A Delta-AN shall allow for measurement of the symmetric (or differential mode – DM) disturbance voltage level between (any) two terminals different from those at ground potential (or conductors or poles, respectively) of the EUT's d.c. power port under test. It shall further allow for measurement of the asymmetric (or common mode – CM) disturbance voltage level at the virtual common HF junction of two (or more) terminals (or conductors or poles, respectively) of the EUT’s d.c. power port under test, relative to laboratory reference ground. For layout and design, the principles set out in CISPR 16-1-2 shall be observed. An example of a suitable Delta-network is found e.g. in CISPR 16-1-2:2014, Clause A.6 Figure A.2. This figure is also replicated in Figure I.2.

I.2.3 AN suitable for measurement of UM, CM and DM disturbances

As an option the Delta-AN may also provide for the measurement of the unsymmetrical mode disturbance voltage level at a single terminal (or conductor or pole, respectively) of the EUT's d.c. power port, relative to laboratory reference ground, just like a V-network. For layout and design, the principles set out in CISPR 16-1-2 shall be observed. Examples for practical implementations of combined pseudo V- and Delta-ANs of several manufacturers are given in Figure I.3 to Figure I.5.

I.3 Employment of DC-ANs for compliance measurements

I.3.1 General

For the measurements, pseudo V-ANs as well as Delta-ANs meeting the requirements in I.4 can be used. Other artificial networks specified in CISPR 16-1-2 can also be used if providing an asymmetric or common mode (CM) 150 Ω termination for the port under test to laboratory reference ground, and if being furnished with an appropriate low CM-blocking capacity decoupling LC-filter.

NOTE Presently the 150 Ω artificial mains V-network specified in CISPR 16-1-2:2014, 4.5 cannot be used for measurements of conducted disturbances at LV d.c. power ports, since providing a common mode termination impedance of 75 Ω only. Such a V-network does not meet the most essential technical parameter specified in Table I.1 Pos. 3, i.e. the value of 150 Ω, for the common mode termination impedance. Negotiations in definition of systematic corrections for measurement results obtained in use of such networks have not been started yet.

Selection of the type of AN is left to the user of this standard. Each type of AN provides for measurement results which have the same confidence level as results obtained when using the established V-network. Information on aspects of measurement uncertainty in respect of artificial mains networks (AMN) is found in CISPR 16-4-2:2011, Clause 4. This information is also valid when employing DC-ANs which comply with the specification in I.4.

If a combined AN is used, then it suffices to just apply it either for measurement of unsymmetrical mode (UM), or for measurement of both, common mode (CD) and differential mode (DM) disturbances.

In any case the assessment of the RFI potential of a given port under test in the frequency range 150 kHz to 30 MHz is only completed, if measurement results were obtained and recorded either for the two composite unsymmetrical mode (UM) disturbance components, or for both, the asymmetric or common mode (CM) and the symmetric or differential mode (DM) disturbance components as well.

I.3.2 Pseudo V-AN

In the pseudo V-network an assessment of these components is only possible in combination as composite unsymmetrical mode (UM) disturbance voltages, the level of which can be different for each terminal of the given port under test, due to internal HF imbalance of the EUT to common ground. These are the “classical” terminal disturbance voltages which can be compared with the established limits directly and which hence constitute the established EMC requirements, for example for a.c. mains ports.

Compliance with the limits is verified only where both measured unsymmetrical mode (UM) disturbance voltage levels are equal to or less than the respective limit.

I.3.3 Delta-AN

In the Delta-network asymmetric or common mode (CM) and symmetric or differential mode (DM) disturbance components can be measured and assessed separately, for each port under test.

Compliance with the limits is verified only where both, the measured common mode (CM) disturbance voltage level and the measured differential mode (DM) disturbance voltage level are equal to or less than the respective limit.

I.4 Normative technical requirements for the DC-AN

I.4.1 Parameters and associated tolerances in the range 150 kHz to 30 MHz

Table I.1 – Parameters and associated tolerances in the range 150 kHz to 30 MHz

Pos.	Description of the parameter	Nominal value and tolerance
1	Type of the DC-AN	Delta-network suitable for measurements at one d.c. power string or port (plus pole, minus pole and reference ground)
2	Calibrated frequency range	150 kHz to 30 MHz (measurement range)
3	CM termination impedance at the EUT port, magnitude	$(150 \pm 30)\,\Omega$
4	CM termination impedance at the EUT port, phase	$(0 \pm 40)°$
5	DM termination impedance at the EUT port, magnitude	$(150 \pm 30)\,\Omega$
6	DM termination impedance at the EUT port, phase	$(0 \pm 40)°$
7	Longitudinal conversion loss (LCL) at the EUT port [a]	≥ 26 dB (symmetrical 150 Ω system) (measured according to CISPR 16-1-2)
8	CM insertion loss AE port – EUT port	≥ 20 dB (asymmetrical 50 Ω system)
9	DM insertion loss AE port – EUT port	≥ 20 dB (symmetrical 150 Ω system) > 40 dB, with external capacitor
10	Discharge resistors for decoupling capacitors in the d.c. current path	≥ 1,5 MΩ

[a] The LCL of the AN should be significantly larger than the internal LCL of the EUT. During the measurement of unsymmetrical disturbance voltages only disturbance components from internal mode conversion DM to CM in the EUT need to be assessed. The statistical mean value of the LCL of installed PV generators has already been taken into account when determining the limits for the DC power input port of GCPCs.

NOTE The parameters in Table I.1 have been derived in developing modern implementations of the 150 Ω CISPR network described in CISPR 16-1-2 for use with measurements at low voltage d.c. power ports of GCPCs for photovoltaic power generating systems.

Measuring ports shall be protected from low frequency components of voltage transients appearing when switching the laboratory d.c. power source on and off. Furthermore, secure galvanic connection shall be guaranteed to the AN's ground in order to drain transient discharge currents through the coupling capacitors when switching the laboratory source off.

Decoupling capacitors in the d.c. current path shall be bypassed with high resistance discharge resistors, see position 10.

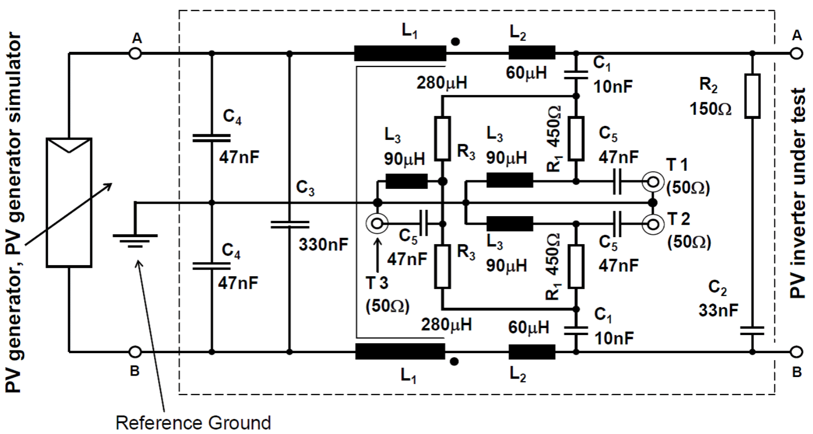
I.4.2 Parameters and associated tolerances in the range 9 kHz to 150 kHz

Table I.2 – Parameters and associated tolerances in the range 9 kHz to 150 kHz

Pos.	Description of the parameter	Nominal values and tolerances
2	Extended frequency range	9 kHz – 150 kHz (includes the operation frequency of GCPCs)
3	CM termination impedance at the EUT port, magnitude	≥ 10 Ω (AE port open)
4	CM termination impedance at the EUT port, phase	not specified
5	DM termination impedance at the EUT port, magnitude	≥ 1 Ω (AE port open)
6	DM termination impedance at the EUT port, phase	not specified
7	Longitudinal conversion loss (LCL) at the EUT port	≥ 26 dB, in the range 10 kHz to 150 kHz (symmetrical 150 Ω system) (measured according to CISPR 16-1-2)
8	CM insertion loss of AE port to EUT port	≥ 20 dB at 150 kHz (asymmetrical 50 Ω system), decreasing with decreasing frequency with 40 dB/decade
9	DM insertion loss of AE port to EUT port	≥ 20 dB at 150 kHz > 40 dB with external capacitor (symmetrical 150 Ω system), decreasing with decreasing frequency with 40 dB/decade

NOTE The parameters in Table I.2 have been derived in developing modern implementations of the 150 Ω CISPR network described in CISPR 16-1-2 for use with measurements at low voltage d.c. power ports of GCPCs for photovoltaic power generating systems.

I.5 Examples of practical implementations of DC-ANs

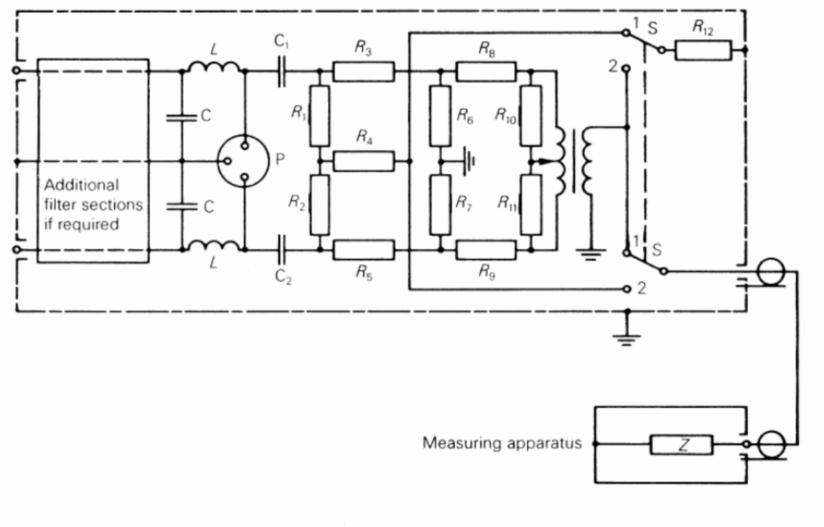


DC-AN with Z_{CM} = 150 Ω , Z_{DM} = 100 Ω . T1, T2 and T3 all terminated with 50 Ω.
Unsymmetrical voltage signals (-20 dB) available at T1 and T2.
Common mode voltage signal (-20 dB ... -24 dB depending on R_3) available at T3.
900 Ω < R_3 < 1 500 Ω depending on the losses in the reactive elements in the realised circuit to match the required impedance tolerance over the whole frequency range.

IEC

NOTE Measuring port T3 can be used for measurement of asymmetric or common mode (CM) disturbance components.

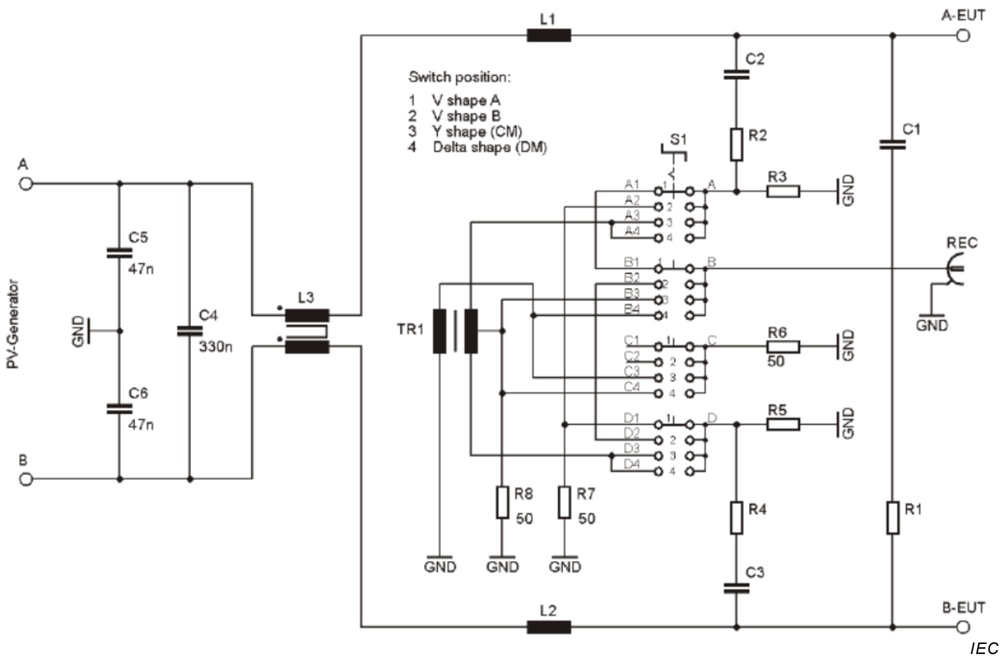
Figure I.1 – Practical implementation of a 150 Ω DC-AN suitable for measurement of UM disturbances (Example)



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

IEC

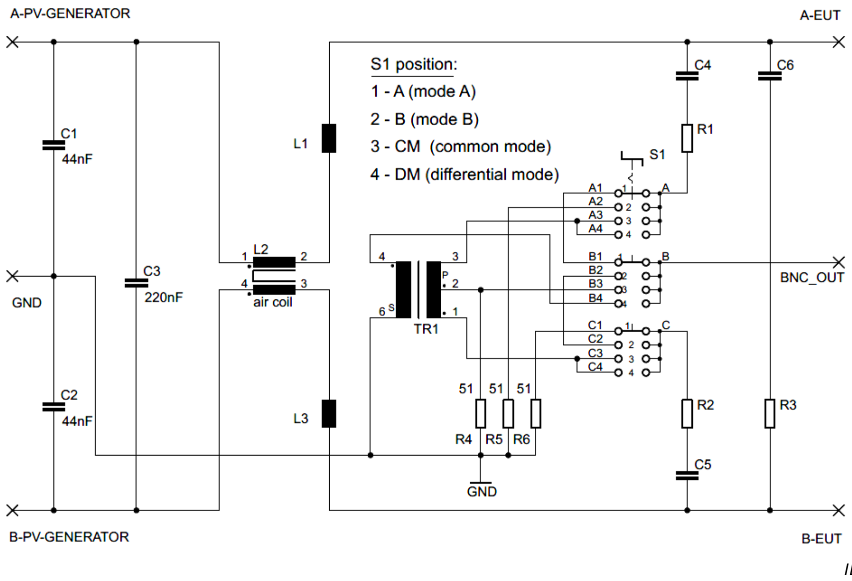
Figure I.2 – Practical implementation of a 150 Ω DC-AN suitable for measurement of CM and DM disturbances (Example, see also Figure A.2 in CISPR 16-1-2:2014)



IEC

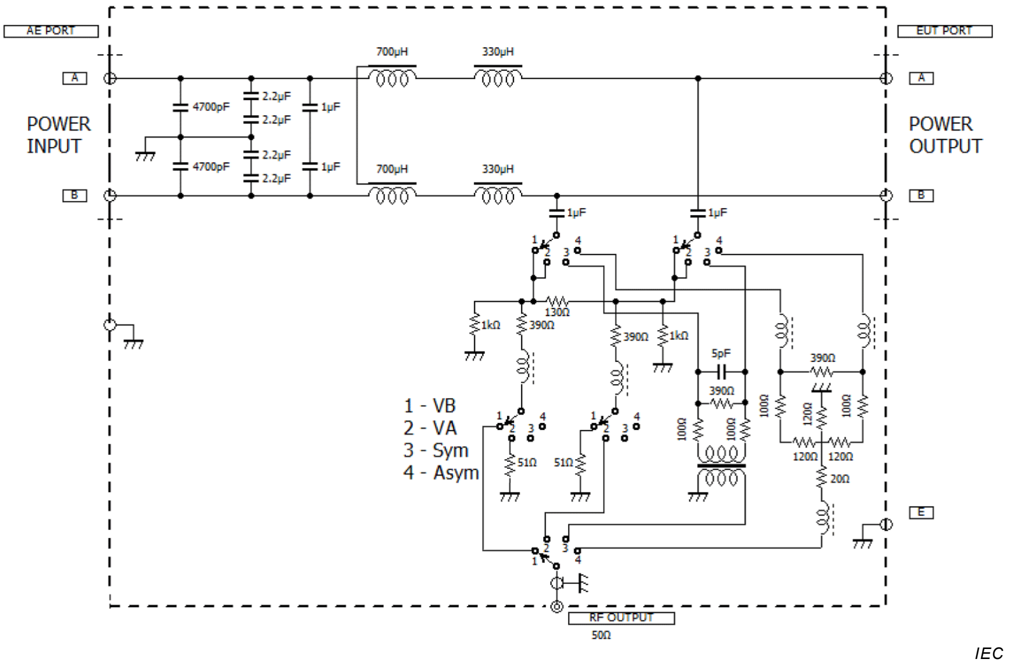
NOTE Mode 1 and mode 2 represent employment of the artificial network for measurement of unsymmetrical mode (UM) or "terminal" disturbance voltages.

Figure I.3 – Practical implementation of a 150 Ω DC-AN suitable for measurement of UM, or CM and DM disturbances (Example 1)



NOTE Mode A and mode B represent employment of the artificial network for measurement of unsymmetrical mode (UM) or "terminal" disturbance voltages.

Figure I.4 – Practical implementation of a 150 Ω DC-AN suitable for measurement of UM, or CM and DM disturbances (Example 2)



NOTE Mode 1 and mode 2 represent employment of the artificial network as pseudo V-network, i.e. for measurement of unsymmetrical or "terminal" disturbance voltages. In use as pseudo V-network, i.e. in mode 1 or mode 2 the DM termination impedance is 100 Ω. In use as Delta-network, i.e. in mode 3 and mode 4, the DM termination impedance is 150 Ω.

Figure I.5 – Practical implementation of a 150 Ω DC-AN suitable for measurement of UM, or CM and DM disturbances (Example 3)

Annex J
(informative)

Measurements on Grid Connected Power Converters (GCPC) – Setups for an effective test site configuration

J.1 General information and purpose

For measurement of disturbance terminal voltages on grid connected power converters (GCPC) intended for supply of electric energy into AC mains grids and similar AC mains installations (see Definition 3.11), connection to an appropriate laboratory DC power supply is necessary on the DC input side of the GCPC, while connection to another appropriate laboratory AC power source or AC mains grid is necessary on the AC output side too.

The DC power is fed into the DC input power ports of the GCPC, and not consumed in the GCPC, and so almost completely converted to AC power and output to the AC side. If the AC power output from the GCPC is not consumed by a resistive load etc., the AC power current can reversely be carried into the laboratory AC power source, and so the equipment may be damaged. In addition, there are some countries where reverse power flow into the AC mains is restricted or prohibited by national law and regulations. Thus, the global setup of the test site used for the measurements needs attention, and a proper and appropriate setup may even enable simplification of the test arrangement and configuration for the equipment under test (EUT). Examples of suitable setups for the test site are described below.

J.2 Setup of the test site

J.2.1 Block diagram of test site

The measurement arrangement and configuration for the EUT can be simplified by use of a test site having a configuration as shown in Figure J.1/J.2. For this setup, the AC output of the GCPC is connected to the AC input of the laboratory DC power supply through the V-AMN used in the measurement arrangement. The laboratory DC power supply converts AC power into DC power, and it is supplied to the DC input of the GCPC. Thus, the current circulates from the AC output to the DC input of the GCPC. The advantages of this site configuration are that the DC power supply consumes the AC output power of the GCPC, and so a resistive load is not required to prevent AC power currents from flowing into the laboratory AC power source.

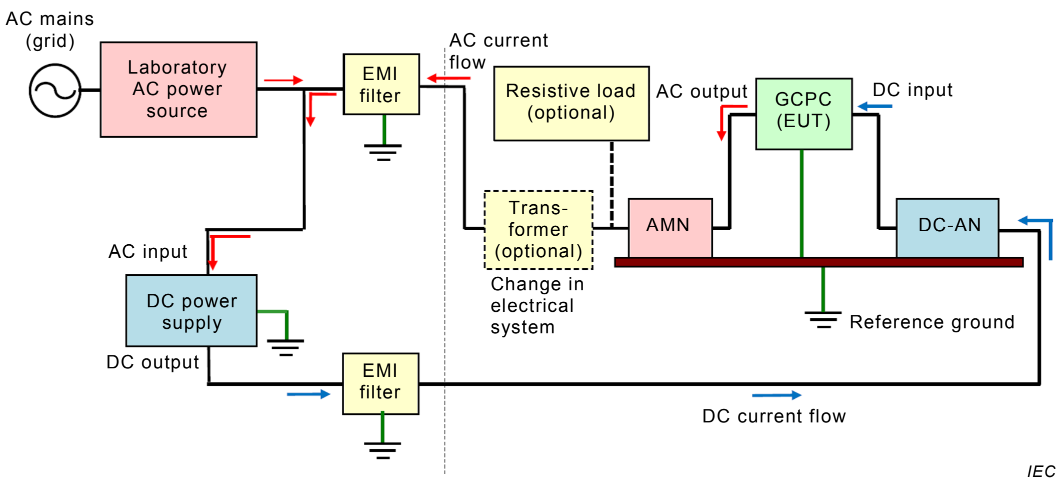
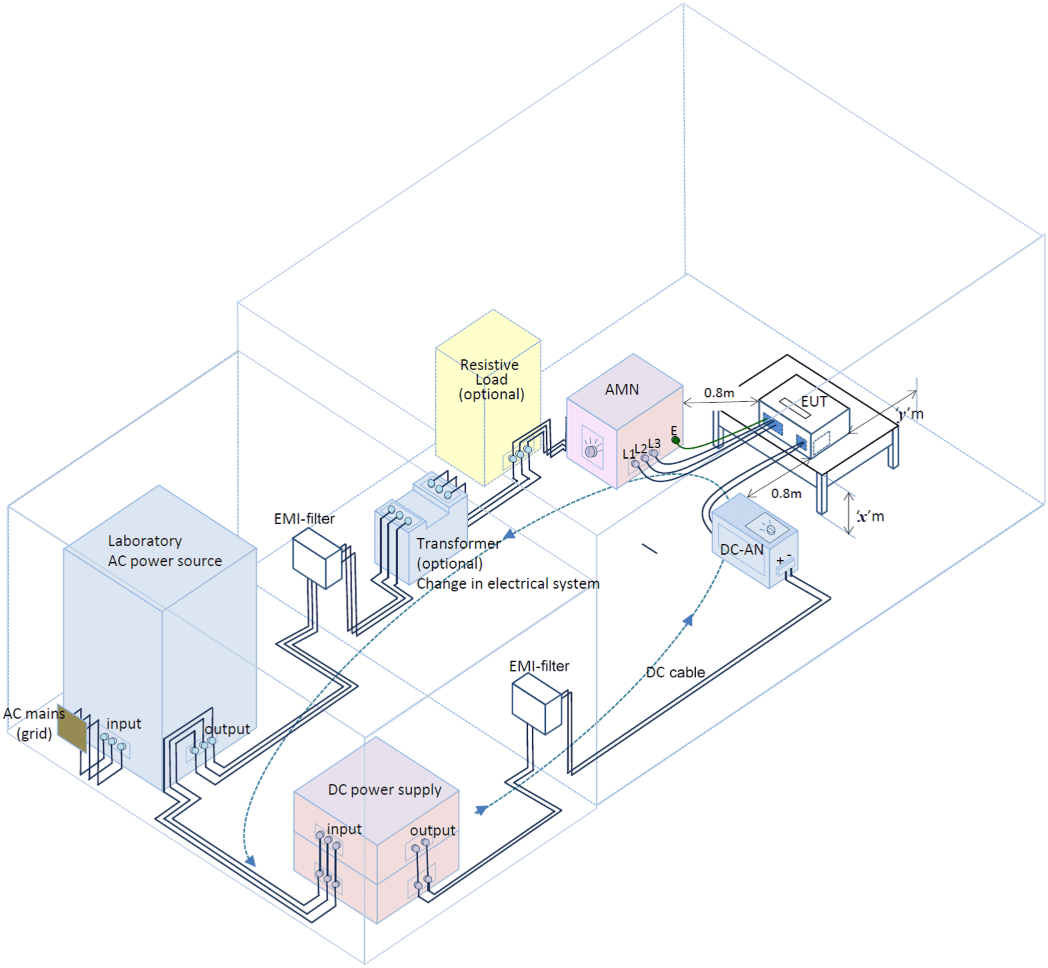


Figure J.1 – Setup of the test site (Case 1) – 2D diagram



NOTE The distances defined as '*x*' and '*y*' in the diagram refer to those as detailed in CISPR 16-2-1:2014, 7.4.1.

Figure J.2 – Setup of the test site (Case 1) – 3D diagram

Consequently the laboratory AC power source needs to provide only the total power losses in the test arrangement, once the measurements are started. Because the laboratory AC power source is used, its AC voltage and frequency can easily be adjusted conforming to the specifications for the AC output side of the GCPC. Reverse AC power current does not flow into the AC power source, and so it cannot be damaged.

J.2.2 DC power supply

The laboratory's DC power supply shall have enough output power to operate the GCPC at its rated AC output power. In addition, a control for adjusting properly its DC output voltage is necessary. In case of the test site setup as shown in Figure J.1/J.2, the electrical system of AC input to the DC power supply shall match with that of the AC output of the GCPC.

J.2.3 AC power source

The laboratory's AC power source shall be of the CVCF-type such that it can adjust to the nominal AC output power voltage and frequency of the GCPC under test. In case of the setup as shown in Figure J.1/J.2, its power is only just enough to supply the total power losses in the test arrangement, and so a larger power is unnecessary.

J.2.4 Other components

In many cases the DC power supply itself is provided with filters on the input and output side. As shown in Figure J.1/J.2, additional EMI filters can be placed on the input and output side of the DC power supply to mitigate conducted disturbances which are generated.

In case the electrical systems of the AC output of the GCPC, the AC input of the DC power supply and the output of the AC power source do not accord like single phase-three-wire, or single phase-two-wire system, a proper transformer shall be inserted as shown in Figure J.1/J.2 to appropriately convert the electrical systems.

J.3 Other test setups

J.3.1 Configuration comprising laboratory AC power source and resistive load

On the other hand, there are some cases where each electrical system cannot basically be matched such as three-phase input of the DC power supply with a single phase AC output of the GCPC (EUT), etc. (there is also the reverse case). In such cases, the AC output of the GCPC cannot directly be connected to the AC input of the DC power supply as shown in Figure J.1/J.2. In this case, another resistive load is connected in parallel with the laboratory AC power source as shown in Figure J.3/J.4 and the AC power of the GCPC (EUT) shall be consumed by that resistive load. As a result, the resistive load prevents the AC output power current of the GCPC from flowing reversely into the laboratory AC power source, if it has enough power to exceed the maximum AC output power of the GCPC.

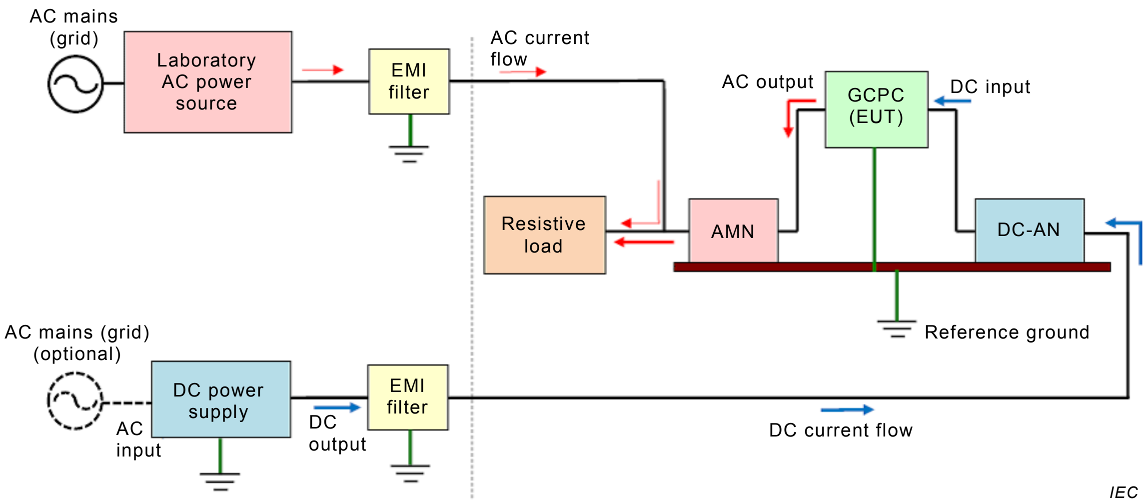
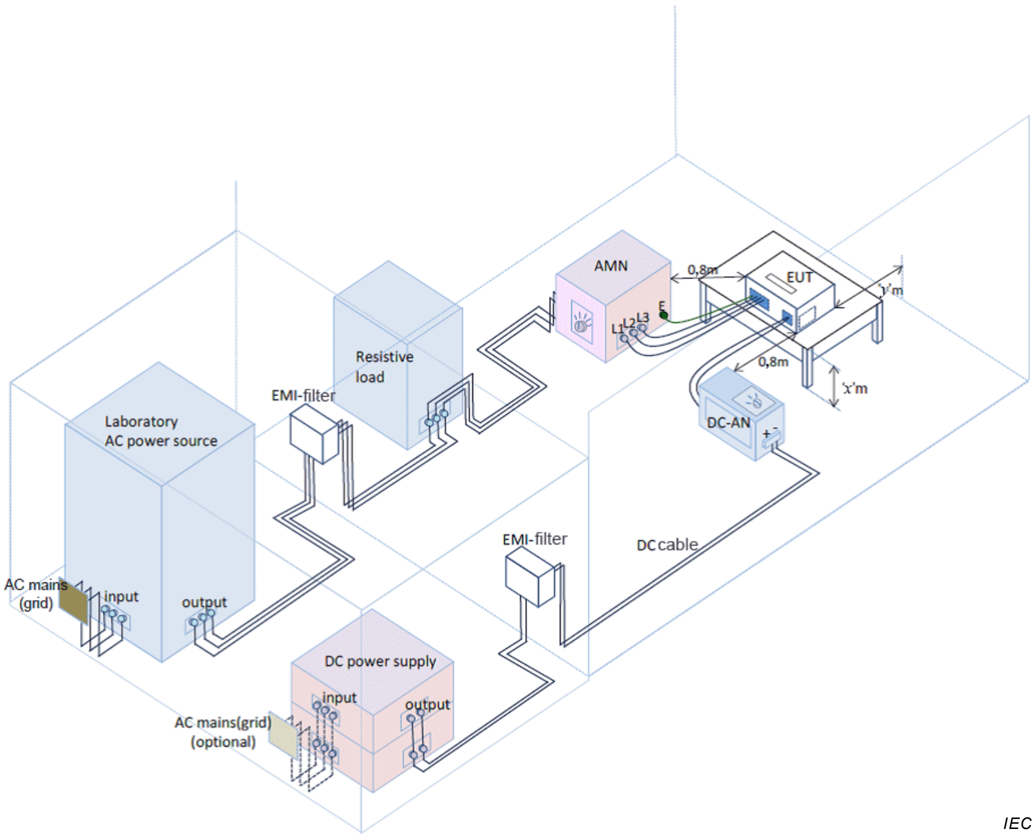


Figure J.3 – Setup of the test site (Case 2) – 2D diagram



NOTE The distances defined as 'x' and 'y' in the diagram refer to those as detailed in CISPR 16-2-1:2014, 7.4.1.

Figure J.4 – Setup of the test site (Case 2) – 3D diagram

J.3.2 Configuration in case of reverse power flow to the AC mains

This setup example shows the case where the laboratory AC power source (see Figure J.3/J.4) is not connected to the AC output side of the GCPC.

In case the AC output of the GCPC is connected to the AC mains through a filter as shown in Figure J.5/J.6, the AC output current of the GCPC flows to the AC mains, and therefore it is not required to connect the resistive load as shown in the previous setup, Case 2. But in this case, there is a disadvantage that the AC power voltage and frequency cannot be adjusted conforming to the specifications of the AC output side of the GCPC.

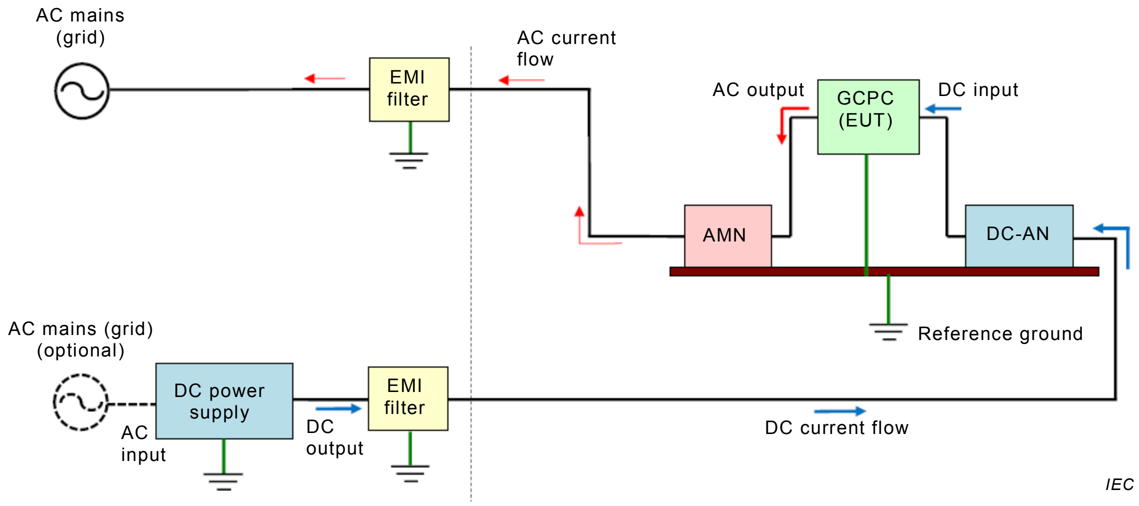
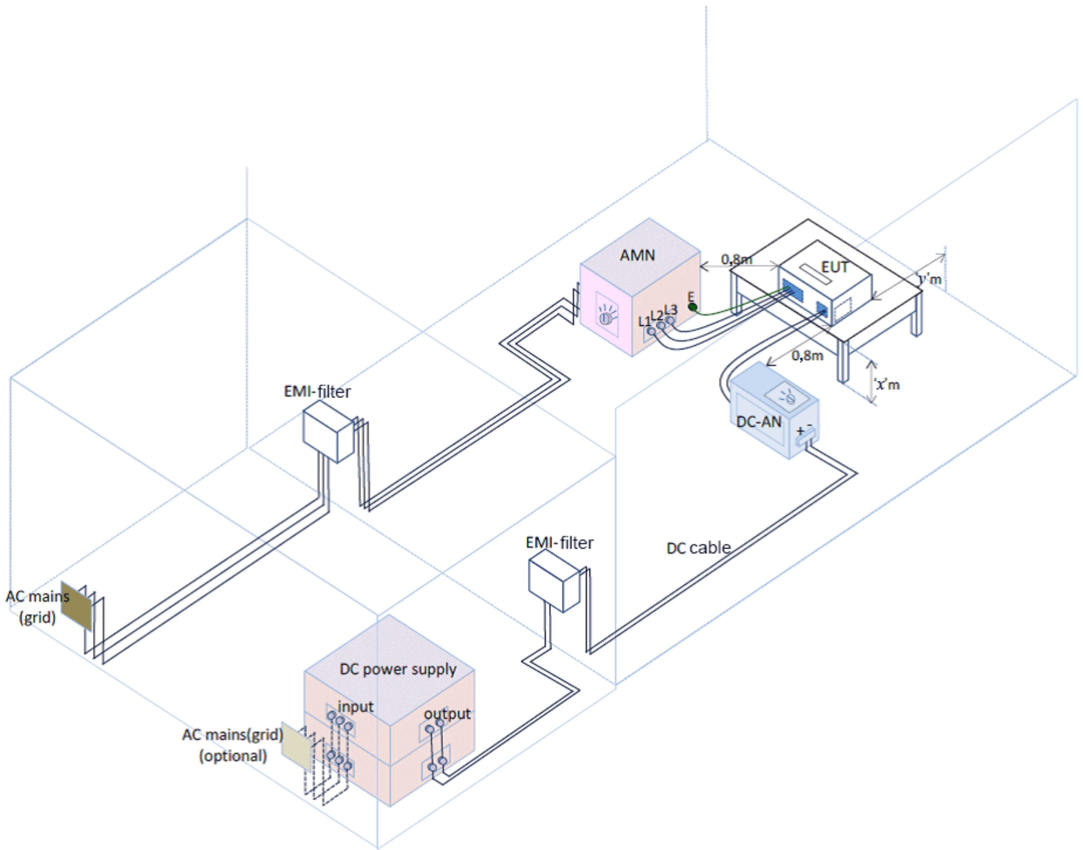


Figure J.5 – Setup of the test site (Case 3) – 2D diagram



NOTE The distances defined as ‘*x*’ and ‘*y*’ in the diagram refer to those as detailed in CISPR 16-2-1:2014, 7.4.1.

Figure J.6 – Setup of the test site (Case 3) – 3D diagram

Annex K
(informative)

Test site configuration and instrumentation – Guidance on prevention of saturation effects in mitigation filters of transformer-less power converters during type tests according to this standard

K.1 General information and purpose

Most types of power converters use operation or switching frequencies in the range of a couple of 100 Hz up to 25 kHz. The measurement results obtained in the range of interest (150 kHz to 30 MHz) are sometimes seriously invalidated by the effective total common mode (CM) impedance of the whole d.c. power supply chain in the test environment in the range of about 500 Hz to 150 kHz. If the operation frequency of the power converter under test coincides with the frequency of the series resonance dip(s) in the effective total common mode (CM) impedance in the whole laboratory d.c. power supply chain, excessive CM disturbance currents may appear at the operation frequency and may saturate the built-in EMI filters (as e.g. common mode chokes) in the EUT. Consequently it will cause serious performance degradation of the filters in the measuring frequency range 150 kHz to 30 MHz. Performance degradation of the filters means that excessive RF disturbance levels will be recorded causing the power converter under test eventually to FAIL proving compliance with the requirements specified in this standard.

It shall be said that such mode of operation of power converters prominently deviates from the operation conditions in normal use. Hence additional countermeasures should be taken at test site configuration level in order to operate the power converters as intended in normal use, in type tests according to this standard.

As a matter of course, CM decoupling capacitors shall be employed, in conjunction with suitable series inductors, as LP-filters decouple the termination impedance at the EUT port of the artificial network (AN) e.g. from influences of the laboratory d.c. power source at the AE port of this AN. The specifications of the DC-AN as in Annex I Table I.2 guarantee that the CM termination impedance at the EUT port of the AN remains at least at values of 10 Ω or more, at the series resonance of its internal LC LP decoupling filter. This will prevent the saturation effects mentioned above in most of the practical testing cases. For the magnitude-versus-frequency characteristics of the CM termination impedance of the AN in the range 9 kHz to 150 kHz, consult the specifications provided by the manufacturer.

Considering now mitigation of common mode RF currents in the whole laboratory d.c. power supply chain at the test site, this mitigation and involved additional CM decoupling capacitors and common mode chokes (as e.g. in the EMI filters at the site) may interact with the characteristics of the built-in LC LP decoupling filter of the AN, and may cause frequency shifts of the series resonance dip(s) of the effective total common mode (CM) impedance experienced at the EUT port of this AN.

It is hence strongly recommended to adjust the magnitude-versus-frequency characteristics of the total effective CM termination impedance at the EUT port of the AN to the conditions needed for the given type of power converter under test. Such adjustments can be made by variation of the value of the CM blocking capacitance in the laboratory's d.c. power supply chain and/or by insert of additional series inductors or common mode chokes. This annex describes possible countermeasures to avoid saturation effects due to unfortunate characteristics of the test site instrumentation used in the laboratory d.c. power supply chain.

Attention is drawn to the user of such test setups in regard of hazardous voltages due to high earth leakage currents. Advice should be sought from duly qualified personnel before switching on the laboratory's system power sources to ensure that injury or damage is not caused to test personnel or equipment.

K.2 Recommendations for avoidance of saturation effects in the range 9 kHz to 150 kHz

If excessive levels of disturbance are observed during measurements of conducted RF disturbances at LV d.c. power ports of power converters in the range 150 kHz to 30 MHz, then this may be caused by saturation effects appearing at the operation frequency of the EUT allocated someplace in the range below 150 kHz. To avoid such conditions it is recommended to observe the guidance given below.

1) For measurements at LV d.c. power ports of power converters use only ANs complying with the technical requirements of the 150 Ω artificial mains Delta-network according to 4.6 of CISPR 16-1-2:2014, or according to Annex I of this standard.
2) Apply good test site engineering and check whether the whole measuring instrumentation (DC-AN excluded) and test site configuration are suitable for use with measurements on power electronics operated in switching mode conditions at operating frequencies (fundamental frequencies) allocated in the range below 150 kHz. Depending on the implemented technology and nominal power throughput, power converters may use fundamental or switching mode frequencies in the range from a couple of 100 Hz up to about 150 kHz.
3) Whenever possible insert additional common mode (CM) absorbing devices such as ferrite tubes, CMADs or also 150 Ω CDNs according to IEC 61000-4-6, between the AE port of the AN and the laboratory d.c. power supply port allocated in the test environment. For this purpose an extended length of the d.c. power supply cable can be used too. In coiled form it introduces an additional decoupling inductor (i.e. a common mode choke) put in series to the laboratory's common mode current circuit. In any case, check the efficiency of the added common mode rejection devices, since for most of them you will not find specifications of technical characteristics in the range below 30 MHz.
4) Avoid coincidence of the fundamental or operating frequency of the power converter under test with the frequency of the series resonance dip in the CM impedance of the whole d.c. power supply chain consisting of the laboratory d.c. power source, the EMI filters used in the installation of the OATS or SAC, and the AN. The frequency of the resonance dip in the CM impedance of the power supply chain can be shifted by changing the capacitance of the effective CM decoupling capacitor. Addition of external CM decoupling capacitors is recommended at the interface between the AE port of the AN and the laboratory d.c. power supply port allocated in the test environment. Be aware that a line of capacitors with different capacitances may be needed if the testing business comprises power converters implementing various technologies, power throughput classes and the like. Remember that the operation frequency may be allocated someplace between a couple of 100 Hz up to about 150 kHz.

K.3 Detailed advice

K.3.1 General

The following descriptions are found for a decoupling circuit of the DC-AN in Clause I.1:

“Further, the DC-AN is furnished with a decoupling network (i.e. an LC-filter) such that sufficient decoupling is provided between its EUT port and its AE port, in order to prevent RF disturbances from the laboratory d.c. power source to affect obtained measuring results. Having asymmetric decoupling capacitors with some 100 nF to about 1 μF capacitance only, the construction of that filter prevents, in most cases, saturation effects in mitigation filters the power converters under test may be furnished with, and this way provides for valid, reliable and repeatable measurement results."

However, if the laboratory d.c. power source is applied in measurement of RF disturbances as shown in Figure K.1, the CM RF current caused by the EUT does not only flow through the decoupling capacitors composing the decoupling circuit of the DC-AN, but also through the decoupling capacitors the laboratory d.c. power source and the EMI filter of the test site are furnished with. In addition, in almost all cases the capacitance of the decoupling capacitors such equipment is furnished with may be much larger than 100 nF.

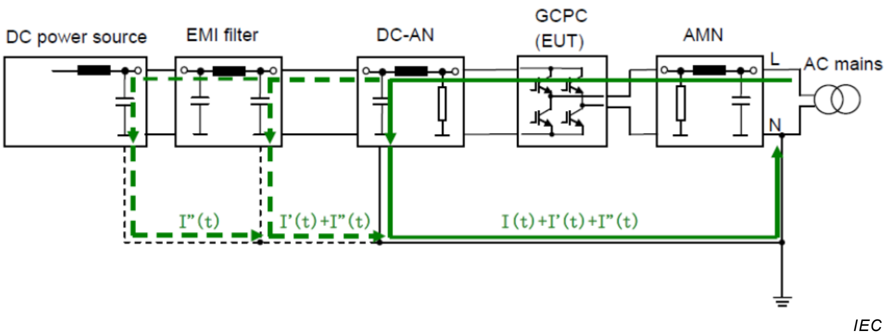


Figure K.1 – Flow of the common mode RF current at test site configuration level

An obvious countermeasure for prevention of these additional contributions to the total effective RF CM current at the operation frequency of the power converter under test is to increase the CM decoupling loss in between the AE port of the DC-AN and the laboratory d.c. power supply port allocated in the test environment.

This decoupling loss can be increased by insert of additional series inductors (preferred countermeasure) and/or by employment of additional CM decoupling capacitors at the interface in between the AE port of the DC-AN and the laboratory d.c. power supply port allocated in the test environment (countermeasure for shifting the frequency of the series resonance dip in the CM termination impedance at the EUT port of the DC-AN).

K.3.2 Insert of series inductors (or common mode chokes) in the laboratory's d.c. power supply chain

If some suitable EMI clamp devices etc. which attenuate the common mode RF current in 9 kHz ~ 150 kHz are inserted between the AE port of the DC-AN and the laboratory d.c. power supply port allocated in the test environment as shown in Figure K.2, the capacitances of the decoupling capacitors the d.c. power source and EMI filter are equipped with can be neglected. For such additional decoupling, extended lengths of d.c. power cable could be used too, if arranged to forming an air coil.

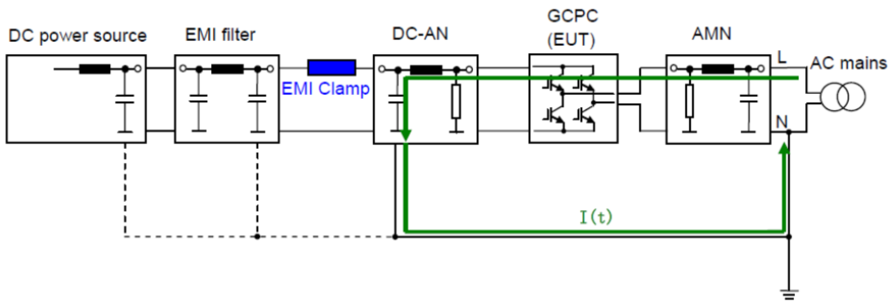


Figure K.2 – Blocking of flow of common mode RF current by insert of series inductors

ATTENTION – Proper equipment such as EMI clamp devices which can attenuate the common mode RF current in the range 9 kHz to 150 kHz may not be available from the market. Preferred measure should hence be insertion of series inductivities.

As mentioned above, because the effective magnitude of capacitance of decoupling capacitors of all the laboratory measuring systems including the laboratory d.c. power source may cause saturation effects in mitigation filters the transformer-less power converter is equipped with, it is necessary to use laboratory d.c. power sources and EMI filters with low capacitance common mode decoupling capacitors only. Observe however that use of CM decoupling capacitors with low capacitance only may also reduce suppression of RF disturbances generated by the laboratory d.c. power source. If extremely large RF disturbances occur during type tests on transformer-less power converters which are thought to be caused by saturation of the built-in mitigation filters, then it should be considered to use batteries as d.c. power source.

K.3.3 Employment of additional common mode decoupling capacitors at the interface between the AE port of the DC-AN and the laboratory d.c. power supply port allocated in the test environment

For an increase of the decoupling loss between the laboratory d.c. power supply chain and the measurement arrangement additional CM decoupling capacitors can be connected between the AE port (i.e. the decoupling circuit) of the DC-AN and the laboratory d.c. power supply port allocated in the test environment as shown in Figure K.3.

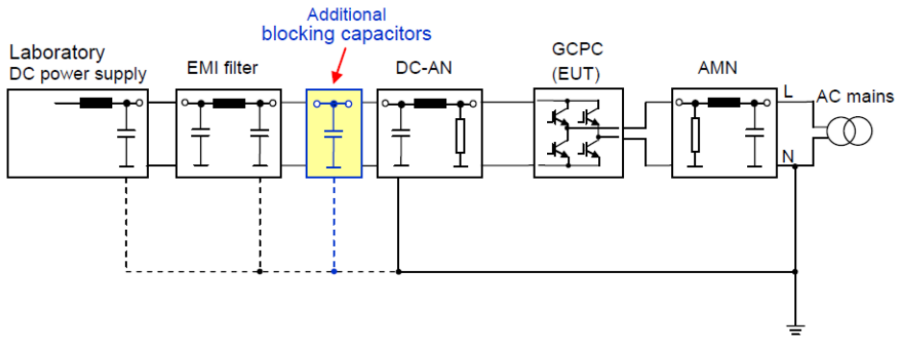


Figure K.3 – Blocking of flow of common mode RF current by employment of additional CM decoupling capacitors

The effect of such a countermeasure is that it shifts the series resonance dip in the magnitude-versus-frequency characteristics of the CM termination impedance at the EUT port of the DC-AN to lower frequencies, this way avoiding possible coincidences in frequency of that resonance dip and the operation or fundamental frequency of the power converter under test. If the operation frequency does not coincide with that series resonance frequency, saturation effects in the EUT can be avoided. It is quite obvious that such a countermeasure shall be carefully adjusted to the given type of power converter, due to the wide range of possibly involved operation frequencies. Individual adjustment of the additional CM blocking capacitance may be necessary in most cases.

K.4 Background information

We studied the methods of solving the saturation problem on the assumption that not a battery, but a laboratory d.c. power supply is used for measurements at transformer-less power converters. Figure K.4 shows an example of common mode impedance characteristics for a DC-AN according to Table I.2. As shown in Figure K.4, it proves that there is a resonant point in the proximity of 20 kHz and the common mode impedance remarkably decreases at this resonant frequency.

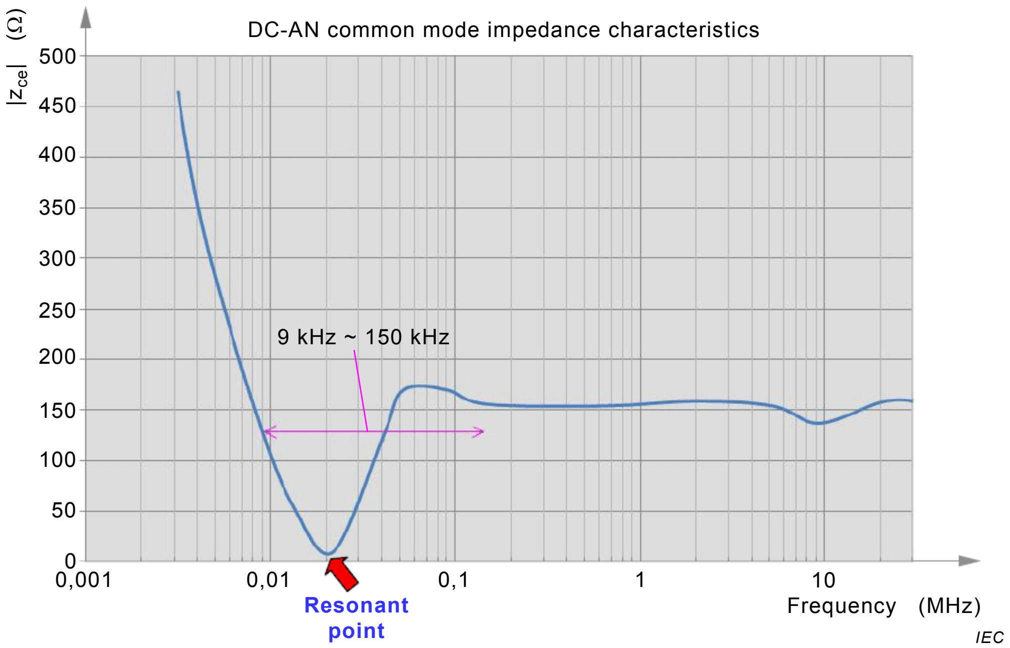


Figure K.4 – CM termination impedance at the EUT port of a DC-AN – Magnitude-versus-frequency characteristic in the range 3 kHz to 30 MHz, Example

The saturation of mitigation filters the power converter is furnished with, that currently becomes a problem, occurs because a large common mode current flows in case the resonant frequency (20 kHz) coincides with the operating frequency of the power converter (EUT). However, the resonant frequency is practically determined not only by the DC-AN, but also by the common mode impedance characteristics of all of the instrumentation used in the whole laboratory d.c. power supply chain including the d.c. power source, installed EMI filters and the like.

In case the effective resonant frequency caused by all of the laboratory measuring instrumentation coincides with the operating frequency of the power converter and so large common mode current flows, or in case it is necessary to confirm whether such conditions actually occur, the resonant frequency can be detuned from the operating frequency of the power converter by changing the capacitance of decoupling capacitors of the decoupling circuit of the DC-AN or adding the capacitance of decoupling capacitors as shown in Figure K.5 and so changing the resonant frequency, that is to say, the resonant point can be shifted as shown in Figure K.6. As a result, the common mode current can be reduced at the operating frequency of the power converter by avoiding saturation effects.

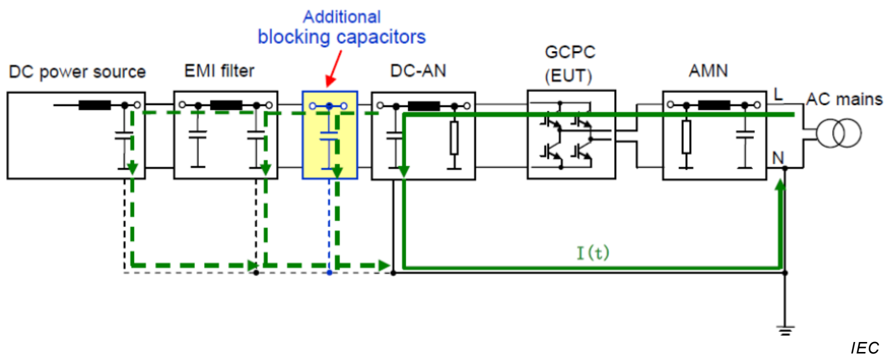


Figure K.5 – Prevention of saturation of mitigation filters by use of additional decoupling capacitors

In other words, if the measurement results in case the capacitance of decoupling capacitors is increased are the same as those in case it is unchanged, it can be concluded that the measurements of conductive disturbances have correctly been performed.

With exchange of hardware components in the DC-AN, it is possible to increase or decrease the capacitance of the CM decoupling capacitors by setting up switches for switching series and parallel connection of these decoupling capacitors as shown in Figure K.7. However, such measure cannot be recommended for application in normal laboratory practice since possibly violating the calibration of the respective DC-AN. However, switched-type combined external CM decoupling capacitors can be used, if necessary. Application of such capacitors will always shift the series resonance of the DC-AN internal LC decoupling filter to lower frequencies than found in the manufacturer's specifications.

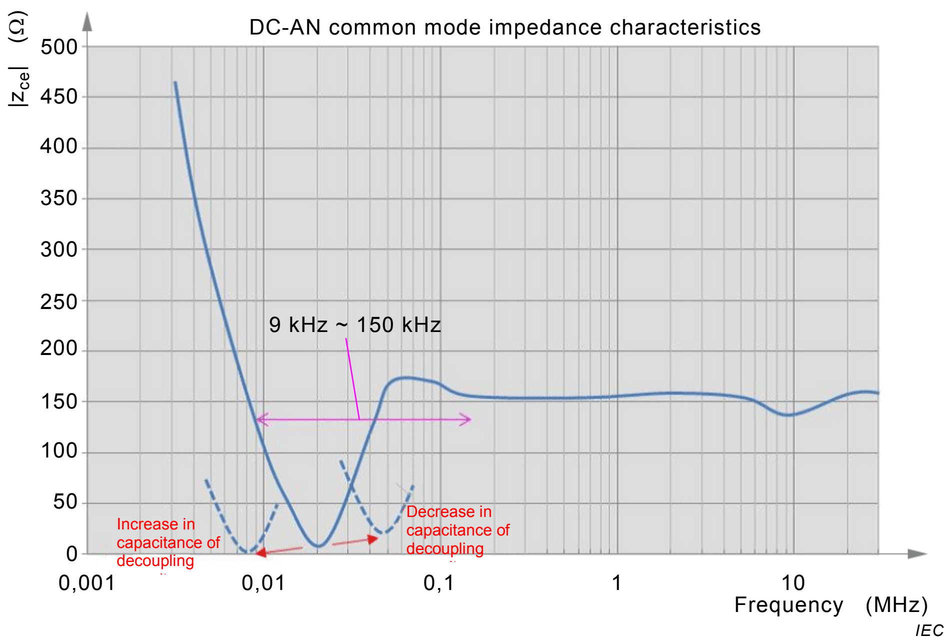


Figure K.6 – Change in the resonant frequency caused by the increase and decrease in the decoupling capacitor's capacitance

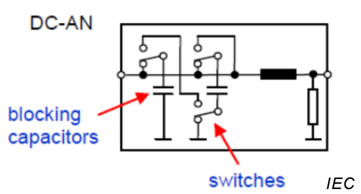


Figure K.7 – DC-AN circuit example where capacitance of blocking capacitors of the LC decoupling circuit can be increased or decreased

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