BS EN 61000-4-31:2017

BSI Standards Publication

Electromagnetic compatibility (EMC)

Part 4-31: Testing and measurement techniques — AC mains ports broadband conducted disturbance immunity test

bsi.

National foreword

This British Standard is the UK implementation of EN 61000-4-31:2017. It is identical to IEC 61000-4-31:2016.

The UK participation in its preparation was entrusted by Technical Committee GEL/210, EMC - Policy committee, to Subcommittee GEL/210/11, EMC - Standards Committee.

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

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

© The British Standards Institution 2017.
Published by BSI Standards Limited 2017

ISBN 978 0 580 79409 4
ICS 33.100.20

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2017.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 61000-4-31

February 2017

ICS 33.100.20

English Version

Electromagnetic compatibility (EMC) - Part 4-31: Testing and measurement techniques - AC mains ports broadband conducted disturbance immunity test (IEC 61000-4-31:2016)

Compatibilité électromagnétique (CEM) -
Partie 4-31: Techniques d'essai et de mesure - Essai d'immunité aux perturbations conduites à large bande sur les accès d'alimentation secteur en courant alternative
(IEC 61000-4-31:2016)

Elektromagnetische Verträglichkeit (EMV) -
Teil 4-31: Prüf- und Messverfahren - Prüfung der Störfestigkeit gegen leitungsgeführte breitbandige Störgrößen an Wechselstrom-Netzanschlüssen
(IEC 61000-4-31:2016)

This European Standard was approved by CENELEC on 2016-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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

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

CENELEC

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

© 2017 CENELEC All rights of exploitation in any form and by any means reserved worldwide for CENELEC Members.

Ref. No. EN 61000-4-31:2017 E

European foreword

The text of document 77B/758/FDIS, future edition 1 of IEC 61000-4-31, prepared by SC 77B “High frequency phenomena” of IEC/TC 77 “Electromagnetic compatibility" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61000-4-31:2017.

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)	2017-08-24
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2020-02-24

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

Endorsement notice

The text of the International Standard IEC 61000-4-31:2016 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

CISPR 16-1-2 NOTE Harmonized as EN 55016-1-2.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60050-161	-	International Electrotechnical Vocabulary (IEV) - Chapter 161: Electromagnetic compatibility	-	-
IEC 61000-4-6	2013	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields	EN 61000-4-6	2014

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-31: Testing and measurement techniques – AC mains ports broadband conducted disturbance immunity test

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61000-4-31 has been prepared by subcommittee 77B: High-frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This standard forms Part 4-31 of the IEC 61000 series. It has the status of a basic EMC publication in accordance with IEC Guide 107.

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

FDIS	Report on voting
77B/758/FDIS	77B/760/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.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)
Definitions, terminology

Part 2: Environment

Description of the environment
Classification of the environment
Compatibility levels

Part 3: Limits

Emission limits
Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques
Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines
Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as International Standards or as Technical Specifications or Technical Reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

This part is an International Standard which gives immunity requirements and test procedure related to conducted broadband disturbances.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-31: Testing and measurement techniques – AC mains ports broadband conducted disturbance immunity test

1 Scope and object

This part of IEC 61000 relates to the conducted immunity of electrical and electronic equipment to electromagnetic disturbances coming from intended and/or unintended broadband signal sources in the frequency range 150 kHz up to 80 MHz.

The object of this standard is to establish a common reference to evaluate the immunity of electrical and electronic equipment when subjected to conducted disturbances caused by intended and/or unintended broadband signal sources on AC mains ports. The test method documented in this standard describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

Equipment not having at least one AC mains port is excluded. The power ports not intended to be connected to AC mains distribution networks are not considered as “AC mains ports” and therefore are excluded.

This standard is applicable only to single phase equipment having rated input current ≤ 16 A; the application of the broadband disturbance to multiple phase equipment and/or equipment with rated input current > 16 A is under consideration.

NOTE As described in IEC Guide 107, this standard is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard is to be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

2 Normative references

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

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility (available at* www.electropedia.org*)*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

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

artificial hand
electrical network simulating the impedance of the human body under average operational conditions between a hand-held electrical appliance and earth

Note 1 to entry: The construction should be in accordance with CISPR 16-1-2.

[SOURCE: IEC 60050-161:1990, 161-04-27, modified – A note to entry has been added.]

3.2
auxiliary equipment
AE
equipment necessary to provide the equipment under test (EUT) with the signals required for normal operation and equipment to verify the performance of the EUT

3.3
common mode impedance
asymmetrical mode impedance between a cable attached to a port and the reference ground plane (RGP)

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

3.4
coupling network
electrical circuit for transferring energy from one circuit to another with a defined impedance

Note 1 to entry: Coupling and decoupling devices can be integrated into one box (coupling/decoupling network (CDN)) or they can be in separate networks.

3.5
coupling/decoupling network
CDN
electrical circuit incorporating the functions of both the coupling and decoupling networks

3.6
coupling/decoupling network for differential mode coupling
CDND
electrical circuit incorporating the functions of both the coupling and decoupling networks that injects the signal primarily in differential mode

3.7
decoupling network
decoupling device
electrical circuit for preventing test signals applied to the EUT from affecting other devices, equipment or systems that are not under test

3.8
differential mode impedance
symmetrical mode impedance between L and N of an AC mains port

3.9
longitudinal conversion loss
LCL
measure, in a one- or two-port network, of the degree of unwanted transverse (symmetric mode) signal produced at the terminals of the network due to the presence of a longitudinal (asymmetric mode) signal on the connecting leads

Note 1 to entry: LCL is a ratio expressed in dB.

[SOURCE: ITU-T O.9:1999, 4.1, modified – The definition has been rephrased and the parentheses have been added.]

3.10
orthogonal frequency-division multiplexing
OFDM
digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers

Note 1 to entry: See ITU-R BT.1306-7:2015.

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

3.11
test generator
generator capable of generating the required test signal

Note 1 to entry: The generator may include the following: white noise source, modulation source, attenuators, broadband power amplifier and filters.

Note 2 to entry: See Figure 3.

3.12
voltage standing wave ratio
VSWR
ratio of a maximum to an adjacent minimum voltage magnitude along the line

4 General

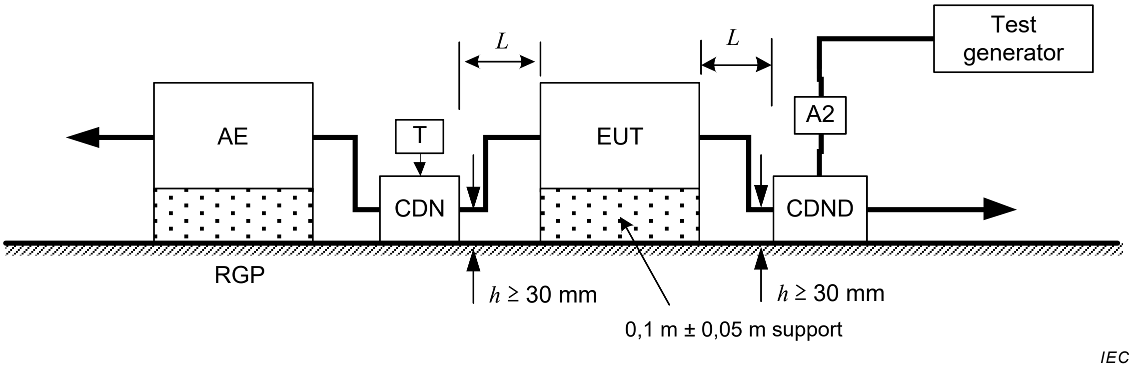
The source of disturbance covered by this standard is basically an intended and/or unintended conducted broadband disturbance superimposed on the mains line to the AC mains port of the EUT.

For example, the signals generated by PLT systems are intentionally-generated broadband disturbances, whereas other electrical and electronic equipment connected to the AC mains network may emit unintentional broadband disturbances.

NOTE Power line telecommunications (PLT) is also known as broadband power line (BPL) and as power line communication (PLC).

Even when the broadband signal is intended to be differential, the unbalance of the mains converts part of it into a common mode signal. To take this phenomenon into account, the disturbance signal is injected through a coupling/decoupling network for differential mode coupling (CDND) having a longitudinal conversion loss (LCL) similar to a typical mains distribution network (see Figure 1).

The characteristics of the CDND are given in 6.2.



Key

A2	optional power attenuator
L	0,1 m ≤ L ≤ 0,3 m
T	termination 50 Ω
CDND	coupling and decoupling network for injection of the test signal primarily in differential mode
CDN	coupling and decoupling network as prescribed in IEC 61000-4-6

Figure 1 – Immunity test to broadband conducted disturbances

With the EUT connected to the CDND, a power attenuator (A2 in Figure 1) of 3 dB or larger shall be inserted between the test generator and the CDND, unless it can be shown that the voltage standing wave ratio (VSWR) due to the mismatch between the test generator and the CDND is ≤ 2.

5 Test levels

The level of the broadband test signal to be applied to the AC power ports under test over the selected frequency range of interest is defined by its power spectral density (PSD) expressed in dBm/Hz and shall be selected from column 2 of Table 1.

For convenience, the test levels are also given for the whole frequency range from 150 kHz to 80 MHz in equivalent voltage spectrum expressed in dB (μV)/100 kHz (see column 3 of Table 1), and in total forward power expressed in dBm (see column 4 of Table 1).

These values were derived in a 50 Ω system using Formula (1) and need to be recalculated if a different or reduced frequency range is selected for the test.

For more details regarding the verification of test levels see also Figure 11.

Table 1 – Test levels

Frequency range 150 kHz to 80 MHz			
Level	**Power spectral density** dBm/Hz	**Equivalent voltage spectrum density** dB (μV)/100 kHz	**Total forward power** dBm
1	–60	97	19
2	–50	107	29
3	–40	117	39
x[a]	Special	Special	Special

NOTE The requirements are in column 2; columns 3 and 4 are added for convenience.

[a] "*x*" can be any level, above, below or in between the others. The level has to be specified in the dedicated equipment specification.

An example of a broadband test signal is shown in Figure 2.

In particular cases of intentional broadband disturbances, product committees may specify a suitable limited frequency range for testing the EUT.

The total forward power for a given power spectral density and selected frequency range can be calculated using Formula (1).

$$P_{\mathrm{TF}} = P_{\mathrm{SD}} + 10\log\left(\frac{f_{\mathrm{stop}} - f_{\mathrm{start}}}{1\ \mathrm{Hz}}\right) \tag{1}$$

where

P_{TF} is the total forward power, in dBm;

P_{SD} is the power spectral density, in dBm/Hz;

f_{stop} is the upper frequency of the test frequency band, in Hz; and

f_{start} is the lower frequency of the test frequency band, in Hz.

The setting procedure of the test levels at the EUT port of the coupling device (CDND) is described in 6.4.

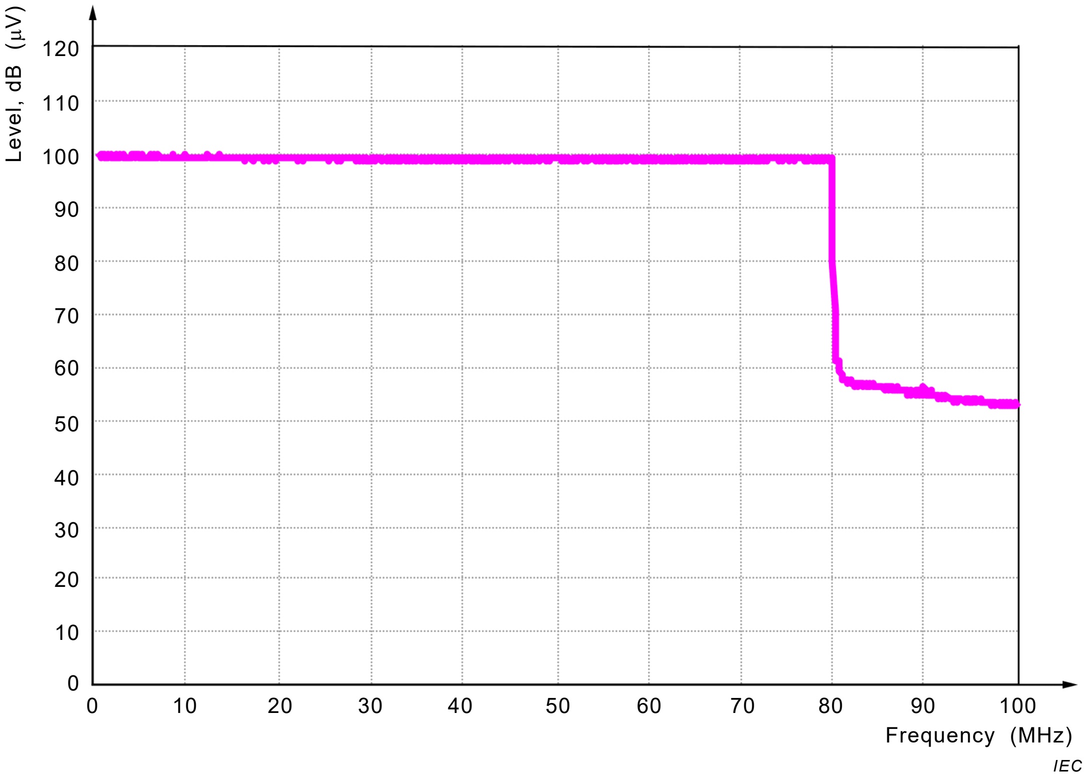


Figure 2 – Example of voltage spectrum of a broadband test signal measured with a 120 kHz resolution bandwidth

6 Test equipment and level setting procedures

6.1 Test generator

The test generator (see Figure 3) includes all the necessary equipment and to provide a broadband input to the CDND that causes the required test signal to be applied to the EUT with the required level, frequency range, modulation, etc.

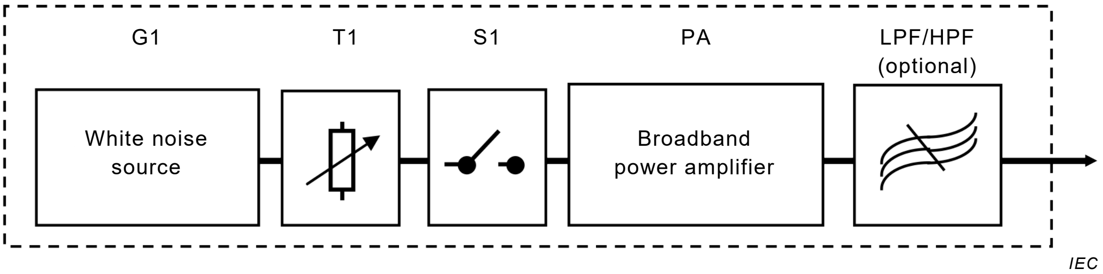
A typical arrangement comprises the following items which may be separate or integrated into one or more test instruments:

- a white noise source, G1, capable of generating a broadband signal over the frequency band of interest. The parameters can be set by manual control or programmable control (e.g. frequency band, amplitude). For more details, see Annex B.
- a pulse modulation capability of 1 Hz and 2 Hz (50 % duty cycle);
- a variable attenuator, A1, (typically from 0 dB to 40 dB) to control the output level of the generated disturbing source, and which is optional;
- an RF switch, S1, by which the disturbing broadband signal can be switched on and off when evaluating the immunity of the EUT. S1 may be included in G1 and is optional;
- a broadband power amplifier, PA, which may be necessary to amplify the signal if the output power of the G1 is insufficient;
- a low-pass filter (LPF), and/or a high-pass filter (HPF), which may be necessary to avoid interference caused by (higher order or sub-) harmonics with some types of EUT, for example RF receivers. When required, they shall be inserted between the output of the broadband power amplifier, PA, and the coupling device (CDND).

The characteristics of the test generator are given in Table 2.

Table 2 – Characteristics of the test generator

Output impedance	50 Ω typical, VSWR < 2
Broadband signal flatness	Within 150 kHz and 80 MHz or capable of covering the frequency band of interest. The flatness of the output signal shall be within ± 3 dB.
Out-of-band contribution above 80 MHz	The output of the test generator shall be at least 20 dB below the specified test level for all frequencies above 100 MHz. Between 80 MHz and 100 MHz the output of the test generator shall not be greater than 3 dB above the target signal level.
Out-of-band contribution below 150 kHz	This contribution is not significant.
If a product committee selects a dedicated frequency range different from 150 kHz to 80 MHz, then the frequency limits for out-of-band contribution should be adjusted accordingly. For example, the out-of-band contribution to the test signal at the output of the test generator should be reduced by at least 20 dB at 37,5 MHz if 30 MHz is chosen as the maximum frequency of the intended test signal.	



Key

G1	White noise source	T1	Variable attenuator
PA	Broadband power amplifier		
LPF/HPF	Low-pass filter and/or high-pass filter (optional)	S1	RF switch

Figure 3 – Principle of the test generator

6.2 Coupling and decoupling devices

6.2.1 General

Coupling devices shall be used to apply the broadband test signal over the frequency range of interest, with a defined common mode and differential mode impedance at the EUT port under test.

Decoupling devices shall be used to prevent the other devices, equipment and systems that are not under test from being disturbed by the test signal.

The coupling and decoupling devices can be combined into one box (a coupling/decoupling network) or can consist of several parts. The preferred coupling and decoupling devices are CDNDs for AC ports and CDNs for all other ports, this is to ensure reproducibility of the test and protection of the AE.

Coupling and decoupling devices shall be used for the following two purposes:

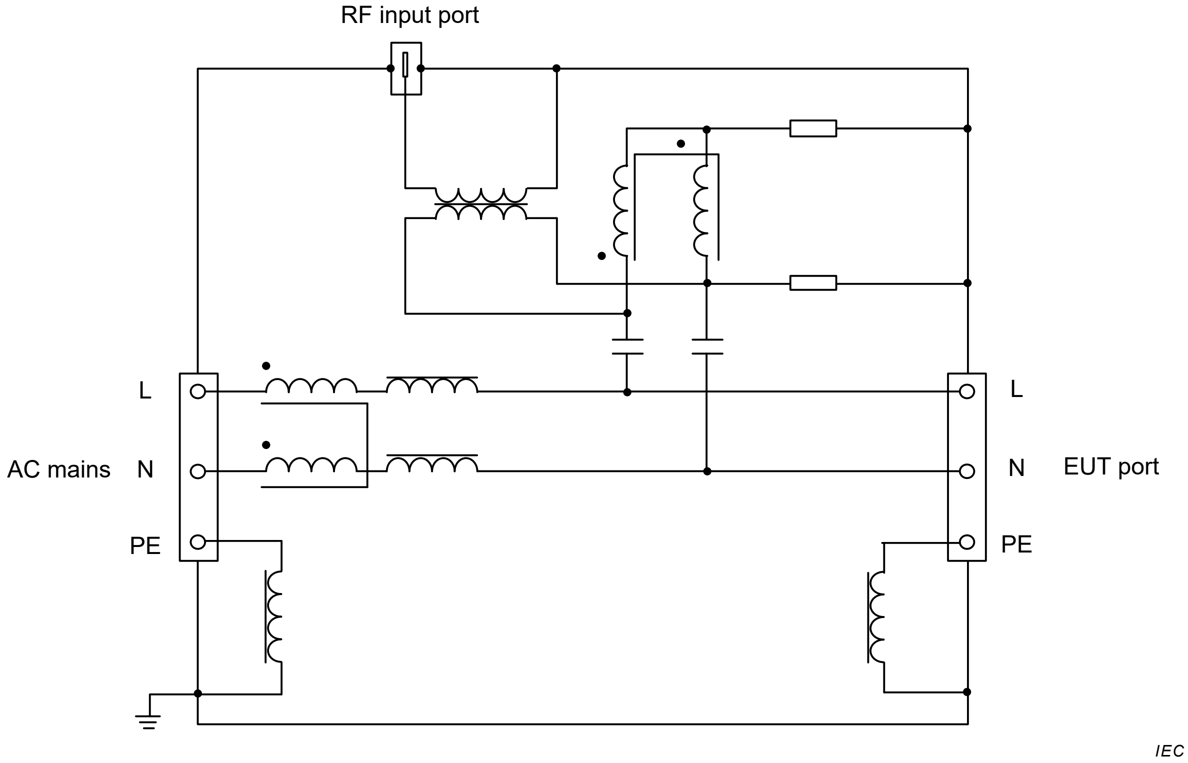
- CDNDs shall be used for the purpose of applying the broadband test signal into the AC mains port under test of the EUT and, where applicable, for decoupling or terminating the AC cables not under test.
- CDNs shall be used for the purpose of decoupling or terminating all other cables (other than AC cables) not under test.

6.2.2 CDND for the port under test

A CDND combines the coupling and decoupling functions in one box and is used to inject the broadband test signal into the AC mains port of the EUT. The CDND shall have a longitudinal conversion loss (LCL) of 16 dB in order to inject the common mode signal as well as the differential mode signal simultaneously. Table 3 and Figure 4 show the basic requirements for CDND and an example of a simplified diagram, respectively.

Table 3 – Specification of the main parameters of the CDND for current ≤ 16 A

Parameter	Common mode (L + N to PE)	Differential mode (L to N)
Frequency range	150 kHz to 80 MHz	150 kHz to 80 MHz
Impedance (EUT port)	25 Ω ± 3 Ω 0° ± 25°	100 Ω ± 25 Ω 0° ± 25°
Insertion loss (RF input port – EUT)	–	3 dB ± 1 dB
Isolation (AC mains port – EUT port)	> 15 dB	> 15 dB
Longitudinal conversion loss (EUT port)	16 dB ± 3 dB	



L, N and PE are mains terminal connections

Figure 4 – Example of simplified diagram for the circuit of CDND

6.2.3 Coupling/decoupling networks (CDNs) for cables that are not under test

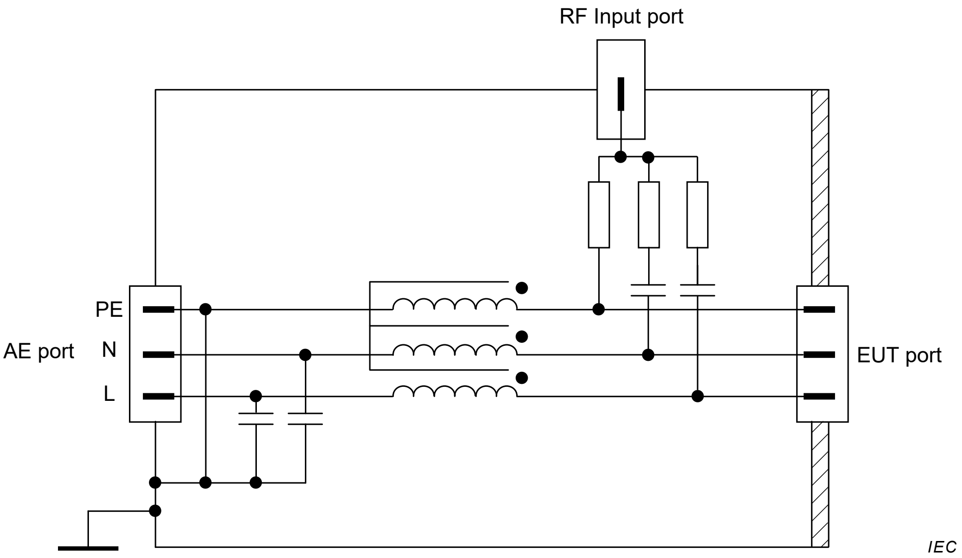
6.2.3.1 General

These networks comprise the coupling and decoupling circuits in one box. An example of a coupling and decoupling network for the use on power ports (other than AC mains) is given in Figure 5. Table 4 summarizes the usage of the different types of CDNs as outlined in IEC 61000-4-6:2013, Annex D. The CDNs selected shall not unduly affect the functional signals. Constraints on such effects may be specified in the product standards.

The CDNs used in 6.2.3 for decoupling circuits or for defining the common mode impedance of the EUT shall be as specified in IEC 61000-4-6.

Table 4 – Usage of CDNs

Line type	Examples	CDN-type
Power ports (other than AC mains) and earth connection	24 V DC in industrial installations, earth connection	CDN-Mx (see IEC 61000-4-6:2013, Figure D.2)
Screened cables	Coaxial cables, cables used for LAN- and USB connections. Cables for audio systems	CDN-Sx (see IEC 61000-4-6:2013, Figure D.1)
Unscreened balanced lines	ISDN-lines, telephone lines	CDN-Tx (see IEC 61000-4-6:2013, Figures D.4, D.5, D.7 and Annex H)
Unscreened unbalanced lines	Any line not belonging to other groups	CDN-AFx or CDN-Mx (see IEC 61000-4-6:2013, Figures D.3 and D.6)



L, N and PE are mains terminal connections

Figure 5 – Example of coupling and decoupling network for power ports other than AC mains

6.2.3.2 CDNs for power supply lines other than AC mains

Coupling/decoupling networks such as CDN-M1, CDN-M2 and CDN-M3 as prescribed in IEC 61000-4-6 shall be used for all power supply connections except the AC mains ports.

6.2.3.3 Unscreened balanced lines

For coupling and decoupling signals to an unscreened cable with balanced lines, CDN-T2, CDN-T4 or CDN-T8 shall be used as specified in IEC 61000-4-6:

- CDN-T2 for a cable with 1 symmetrical pair (2 wires);
- CDN-T4 for a cable with 2 symmetrical pairs (4 wires);
- CDN-T8 for a cable with 4 symmetrical pairs (8 wires).

6.2.3.4 Coupling and decoupling for unscreened unbalanced lines

For coupling and decoupling signals to an unscreened cable with unbalanced lines, a suitable CDN-X as defined in IEC 61000-4-6 can be used, for example CDN-AF2 for two wires or CDN-AF8 for 8 wires.

6.2.3.5 Coupling and decoupling for screened cables

For coupling and decoupling signals to a screened cable, for example, CDN-S1 can be used as prescribed in IEC 61000-4-6.

6.2.3.6 Decoupling networks

The decoupling network generally comprises several inductors to create and maintain a high impedance value over the testing frequency range. This inductance determined by the ferrite material used shall be at least 280 μH at 150 kHz.

The reactance shall remain high, ≥ 260 Ω up to 24 MHz and ≥ 150 Ω above 24 MHz. The inductance can be achieved either by having a number of windings on ferrite toroids or by using a number of ferrite toroids over the cable (usually as a clamp-on tube).

NOTE The specification for clamps is given in IEC 61000-4-6.

The CDNs can be used as decoupling networks with the RF input port left unloaded. When CDNs are used in this way, they shall meet the requirements of IEC 61000-4-6.

6.3 Verification of the test systems

6.3.1 General

The test system (including the test generator and the CDND) shall have the capability to apply a constant and flat broadband test signal to the AC mains port of the EUT over the test frequency range.

The characteristics of the test generator and the CDND are described in 6.1 and 6.2.2 and parameters are given in Tables 2 and 3 respectively.

The verification of the flatness and level setting of the broadband test signal applicable to the EUT are described in 6.3.2 to 6.4.

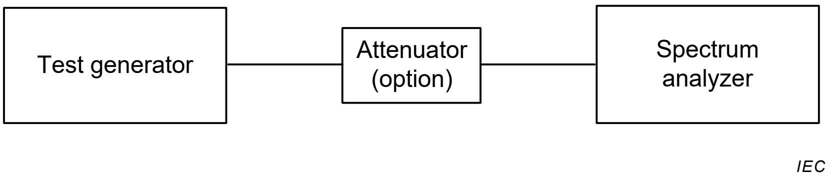
6.3.2 Verification procedure of test generator flatness

The broadband signal provided by the test generator to the CDND shall satisfy the flatness requirement of ± 3dB over the test frequency range.

The verification of the signal flatness over the test frequency range shall be performed using a spectrum analyser and measured in a resolution bandwidth of (100 ± 30) kHz.

The measurement set-up is illustrated in Figure 6a), and the typical output test generator signal is illustrated in Figure 6b).

NOTE Information on test signal generation is given in Annex B.



The optional attenuator is selected to prevent overload or damage of the spectrum analyzer.

Figure 6a) – Set-Up for the verification of the output broadband signal of test generator

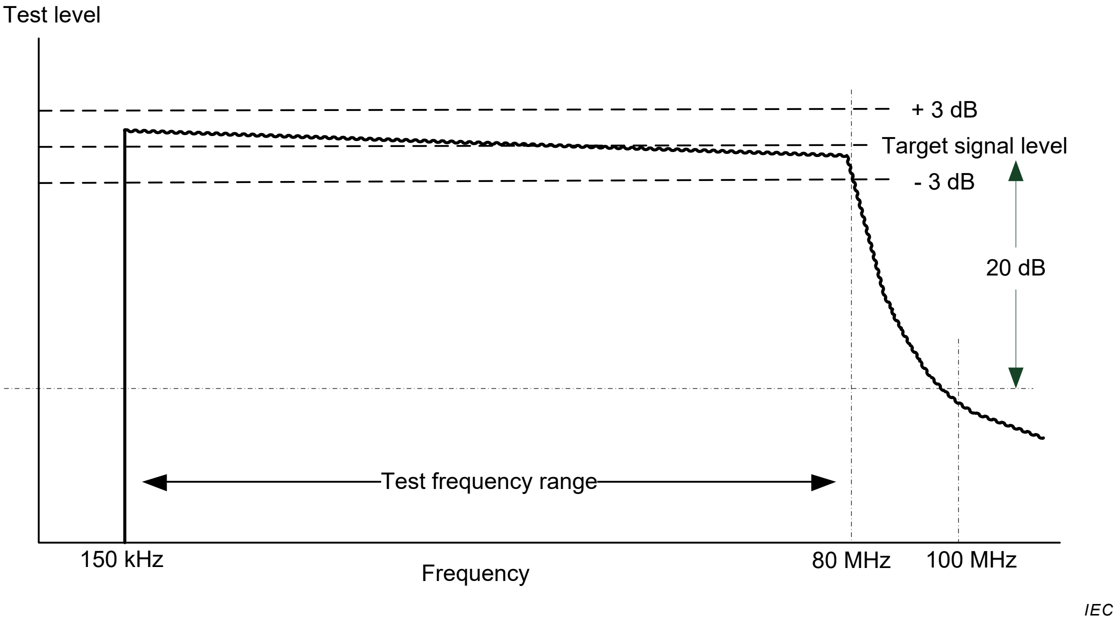


Figure 6b) – Typical spectrum of the output broadband signal of test generator

Figure 6 – Test set-up regarding test generator flatness and typical test signal

6.3.3 Verification procedure of the insertion loss of the CDND using transformer jigs

Transformer jigs shall be used to verify the symmetrical signal level coupled between line and neutral and the characteristics of the injection coupling system (which in part includes the CDND). When a test signal is injected into the RF input port of a CDND, the transformer jig is used to verify the symmetrical signal level coupled between L and N.

These transformer jigs convert the input impedance from an asymmetrical 50 Ω input/output into a symmetrical 100 Ω input/output over the whole applicable test frequency range. An example of a circuit for the transformer jig is shown in Figure 7.

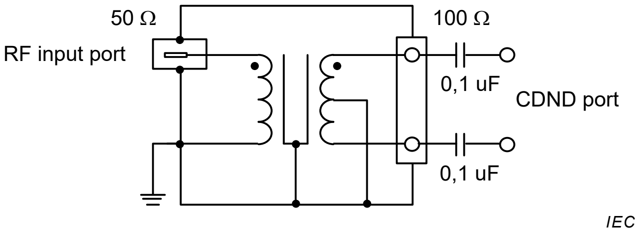


Figure 7 – Typical circuit diagram of the transformer jig showing 50 Ω side and 100 Ω side of the transformer and 2 pcs 0,1 μF coupling capacitors

The insertion loss of the transformer jigs shall be measured according to the principle given in Figures 8a) to 8c). Three independent measurements shall be performed in order to determine the insertion loss of each transformer jig as well as the CDND.

First, the vector network analyzer (VNA) shall be calibrated at the cable ends using a full 2-port through-open-short-match (TOSM) calibration. The VNA may be replaced by a signal generator and a receiver, if a VNA is not available. Then, the measurements according to the principle given in Figures 8a) to 8c) shall be performed (the AC mains port of the CDND is differentially terminated with 100 Ω). The insertion loss of the transformer jigs and the CDND is calculated as follows:

Transformer jig 1:	$A_1 = 0{,}5 \times (A_{12} + A_{13} - A_{23})$
Transformer jig 2:	$A_2 = 0{,}5 \times (A_{12} + A_{23} - A_{13})$
CDND:	$A_3 = 0{,}5 \times (A_{13} + A_{23} - A_{12})$

where

A_1	is the insertion loss of transformer jig 1;
A_2	is the insertion loss of transformer jig 2;
A_3	is the insertion loss of the CDND;
A_{12}	is the sum of insertion losses of transformer jig 1 and Transformer jig 2 (see Figure 8a));
A_{13}	is the sum of insertion losses of transformer jig 1 and CDND (see Figure 8b));
A_{23}	is the sum of insertion losses of transformer jig 2 and CDND (see Figure 8c)).

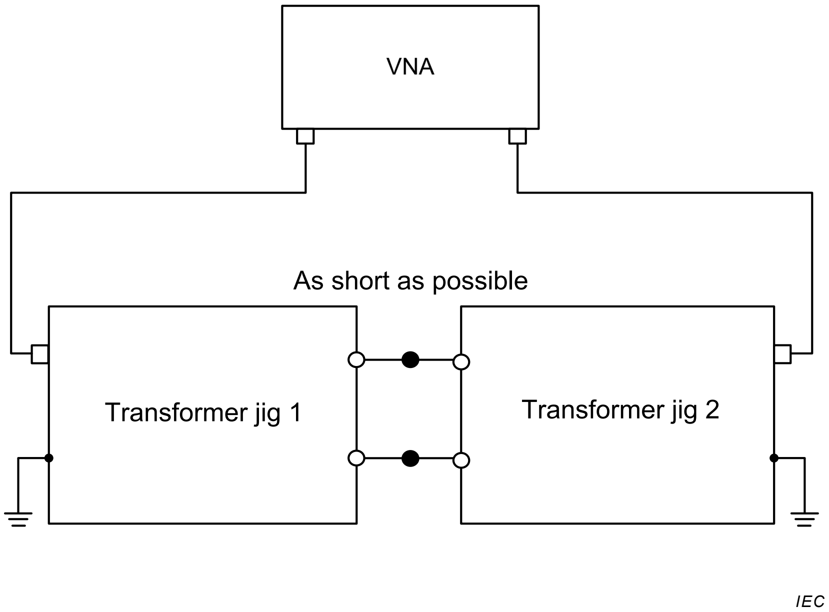
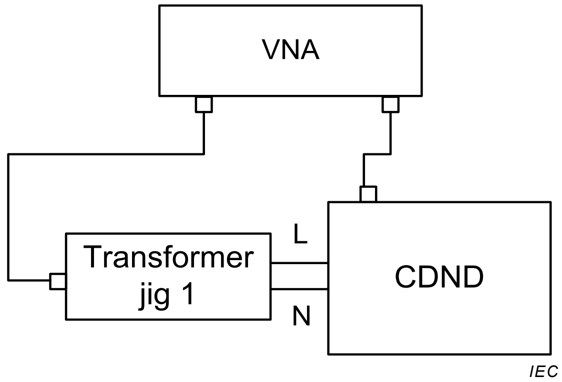
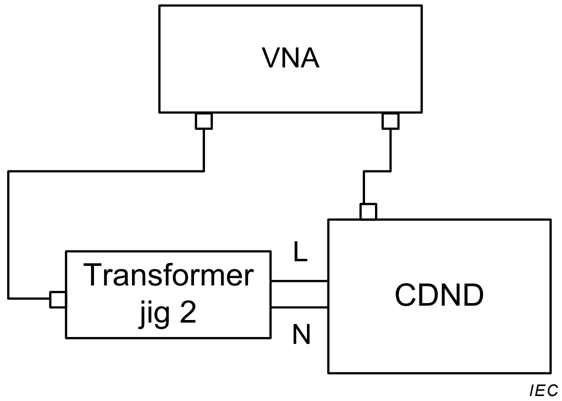


Figure 8a) – Insertion loss measurement set-up of the transformer jig measurement A_{12}



L and N are mains terminal connections

Figure 8b) – Insertion loss measurement set-up of the transformer jig measurement A13



L and N are mains terminal connections

Figure 8c) – Insertion loss measurement set-up of the transformer jig measurement A23

Figure 8 – Transformer jig specifications

The insertion loss of the transformer jigs shall be less than 1 dB over the applicable frequency range. The flatness of the insertion loss of the CDND shall not exceed ± 1 dB. Typical values for the insertion loss of the CDND are in the range of 2 dB to 4 dB.

6.3.4 Insertion loss of the injection coupling system

In order to verify the insertion loss of the injection coupling system, the test set-up as shown in Figure 9 shall be used.

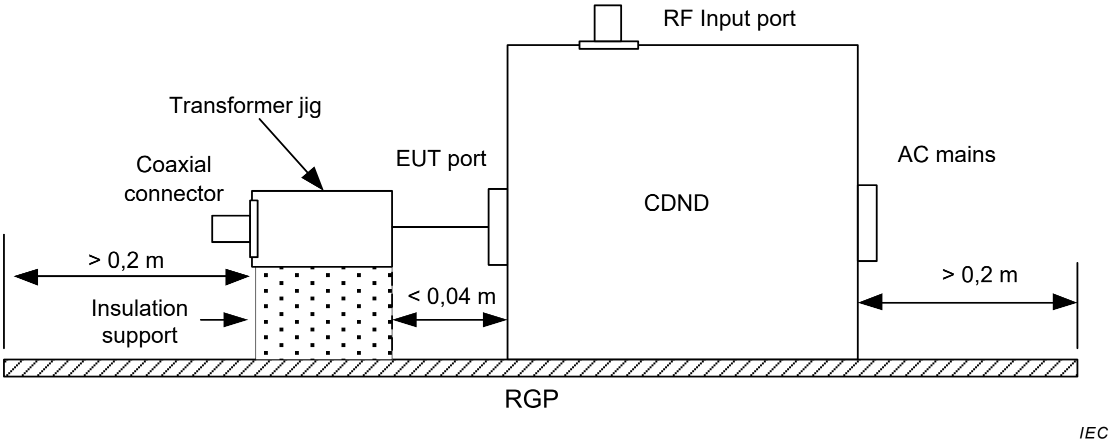
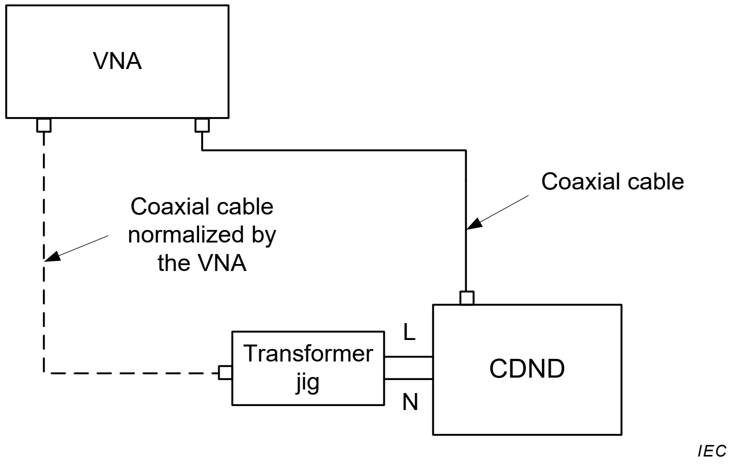


Figure 9 – Example of the set-up geometry to verify the insertion loss of the injection coupling system

The reference ground plane shall extend at least 0,2 m beyond the perimeter of the set-up. The height of the insulation support under the transformer jig is adjusted to minimize the cable length between the transformer jig and the CDND.

The flatness of the insertion loss of the injection coupling system (comprising the coaxial cables, the attenuator, the CDND and the transformer jig) used for testing shall be verified using a vector network analyser (VNA) as illustrated in Figure 10, and shall be within ± 3,0 dB.

NOTE The VNA can be replaced by a signal generator and a receiver.



L and N are mains terminal connections

Figure 10 – Set-up for the evaluation of the total insertion loss of the injection coupling system

6.4 Test level setting procedure

6.4.1 General

For the correct setting of the level of broadband signal injected by the test generator at the RF input port of the CDND, the procedure in 6.4.2 shall be applied. It is assumed that the test generator, the CDND and the transformer jig comply with the requirements of 6.2 and 6.3.

6.4.2 Setting of the output level at the EUT port of the CDND

The set-up used to adjust the output power of the broadband signal to the required level for testing is given in Figure 11.

The test generator shall be connected to the RF input port of the CDND. The EUT port of the CDND shall be connected through the transformer jig to the measuring equipment having a 50 Ω input impedance. The AC mains port of the CDND shall be loaded with a second transformer jig, terminated with 50 Ω.

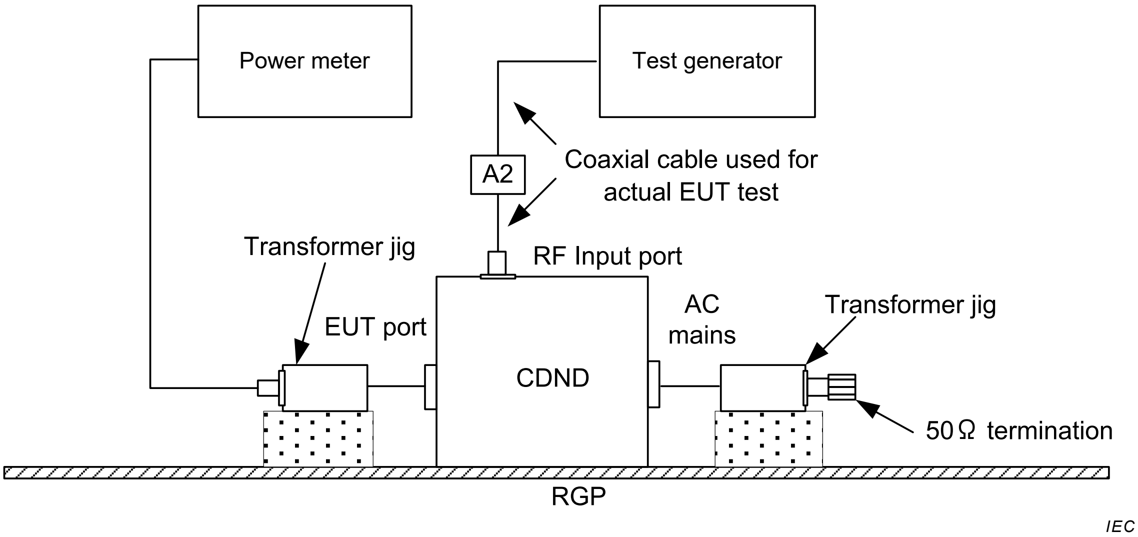
The broadband test signal power measurement should preferably be performed using a thermocouple type power meter. Other power meter types may be used, if their suitability (especially linearity) is proven.

Using the described set-up and the following measurement procedure, the test generator shall be adjusted to yield the following reading on the measuring equipment.

The steps to be followed are:

a) The target total forward power is calculated using Formula (1) in Clause 5, according to a selected test level of Table 1 and for the frequency range of interest for testing the EUT.

b) The output of the test generator shall be adjusted to get a total forward power reading measured by the power meter at the output of the transformer jig connected to the EUT port of the CDND as determined in step a) (see Figure 11). The generator settings required to achieve that test level shall be recorded and shall be used for testing the EUT.



Key

A2 optional power attenuator

Figure 11 – Set-up for level setting

7 Test set-up and injection methods

7.1 Test set-up

The EUT shall be placed on an insulating support of (0,1 ± 0,05) m height above a reference ground plane. A non-conductive roller/caster in the range of (0,1 ± 0,05) m above the reference ground plane can replace the insulating support. All cables exiting the EUT shall be supported at a height of at least 30 mm above the reference ground plane.

If the equipment is designed to be mounted in a panel, rack or cabinet, then it shall be tested in this configuration. When a means is required to support the test sample, such support shall be constructed of a non-metallic, non-conducting material.

The cable attached to the AC mains port under test of the EUT shall be connected to the CDND EUT port for applying the broadband test signal. In case of multiple AC mains port, each cable shall be connected to a CDND. All other cables shall be connected to CDNs and/or decoupling devices. They shall be located between 0,1 m and 0,3 m from the EUT (distance L in this standard). This distance is to be measured horizontally from the projection of the EUT onto the reference ground plane to the CDND, CDNs and/or decoupling devices. See Figure 13 for additional reference.

NOTE Distance L is not necessarily the same on all sides of the EUT, but is between 0,1 m and 0,3 m.

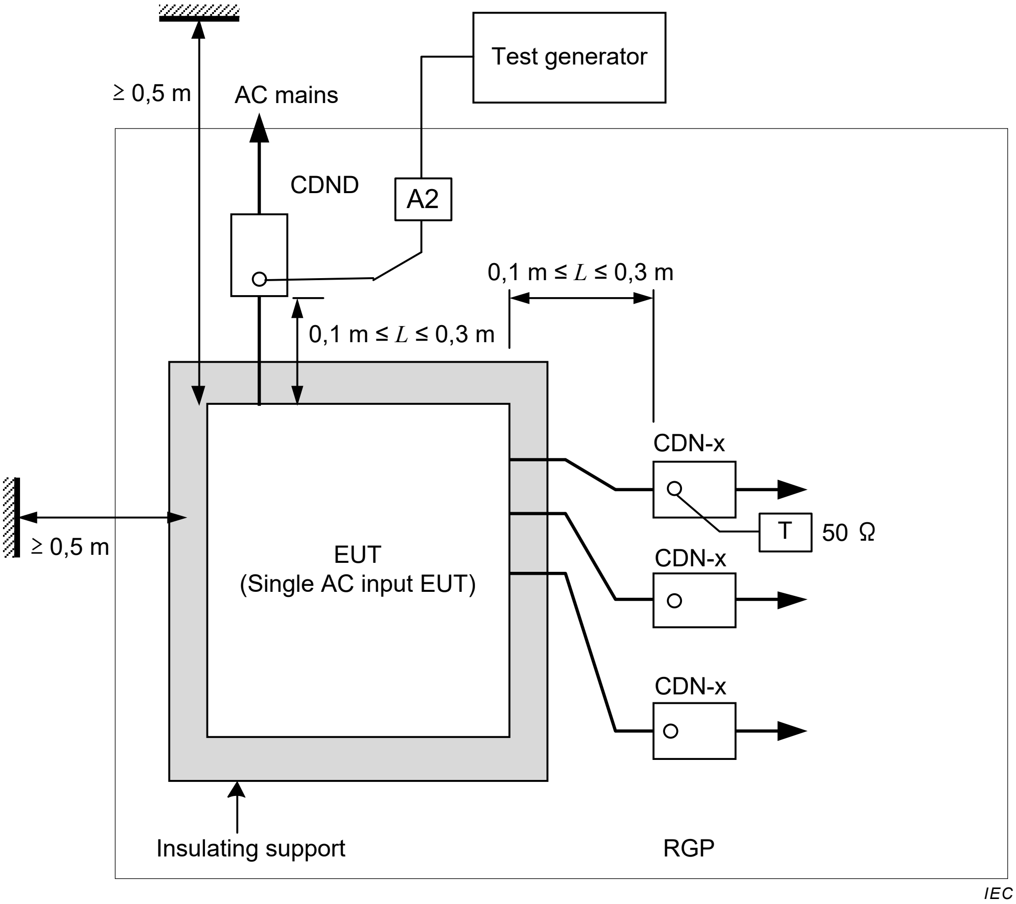
7.2 EUT comprised of a single unit

The EUT shall be placed on an insulating support above the reference ground plane. For table-top equipment, the reference ground plane may be placed on a table (see Figure 12). Only one CDN or CDND shall be terminated (see 7.4).

The coupling and decoupling devices shall be placed on the reference ground plane, making direct contact with it, at a distance of 0,1 m to 0,3 m from the EUT. The cables between the coupling and decoupling devices and the EUT shall be as short as possible and shall not be bundled or wrapped. They shall be placed or supported at a height of at least 0,03 m above the reference ground plane. If the EUT is provided with other earth terminals, they shall, when allowed, be connected to the reference ground plane through the coupling and decoupling network CDN-M1.

If the EUT is provided with a keyboard or hand-held accessory, then the artificial hand shall be placed on this keyboard or wrapped around the accessory and connected to the reference ground plane.

The auxiliary equipment (AE) required for the defined operation of the EUT according to the specifications of the product committee (communication equipment, modem, etc.), as well as the auxiliary equipment necessary for ensuring any data transfer and assessment of the functions, shall be connected to the EUT through coupling and/or decoupling devices. At least one of each type of physical ports should be connected to a cable, and decoupled as described in 7.1.



Key

T termination 50 Ω

A2 optional power attenuator

The EUT clearance from any metallic objects other than the test equipment shall be at least 0,5 m. Only one of the CDNs not used for injection shall be terminated with 50 Ω providing only one return path. All other CDNs shall be configured as decoupling networks.

Figure 12 – Example of test set-up for an EUT comprised of a single unit (top view)

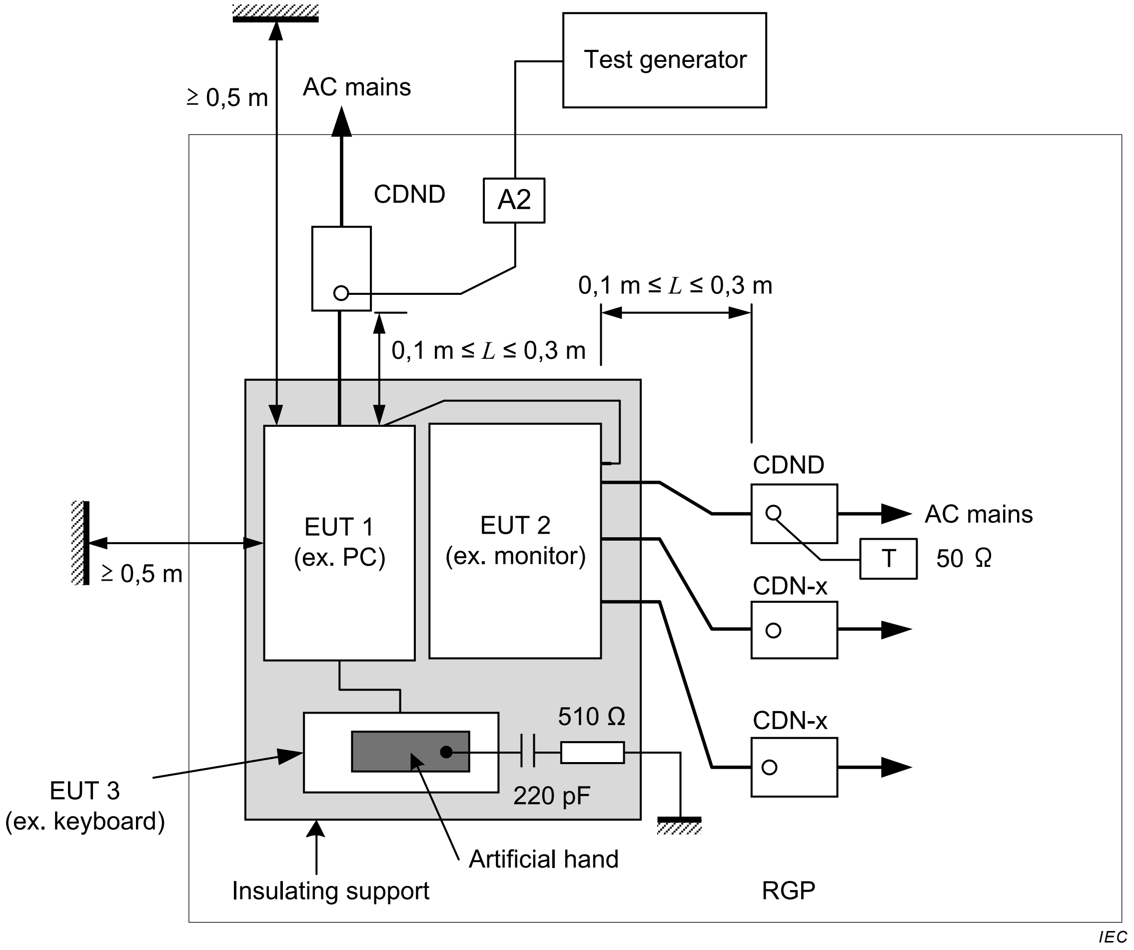
7.3 EUT comprised of several units

Equipment comprised of several units, which are interconnected, shall be tested using one of the following methods.

- Preferred method: Each sub-unit shall be treated and tested separately as a unique EUT (see 7.2), considering all the others units as AE. CDNs or decoupling networks shall be placed on the cables connected to the sub-units considered as the EUT. The AC mains ports of all sub-units shall be tested separately.
- Alternative method: Sub-units that are always connected together by short cables, i.e. ≤ 1 m, and that are part of the equipment to be tested can be considered as a unique EUT. These interconnected cables are then regarded as internal cables of the system. See Figure 13.

  The units being part of such an EUT shall be placed as close as possible to each other without making contact, all on the insulating support. The interconnecting cables of these units shall also be placed on the insulating support.

The EUT clearance from any metallic obstacles other than the test equipment shall be at least 0,5 m.



Key

T termination 50 Ω

A2 optional power attenuator

The EUT clearance from any metallic objects other than the test equipment shall be at least 0,5 m. Only one of the CDNs not used for injection shall be terminated with 50 Ω, providing only one return path. All other CDNs shall be configured as decoupling networks.

Interconnecting cables (≤ 1 m) belonging to the EUT shall remain on the insulating support.

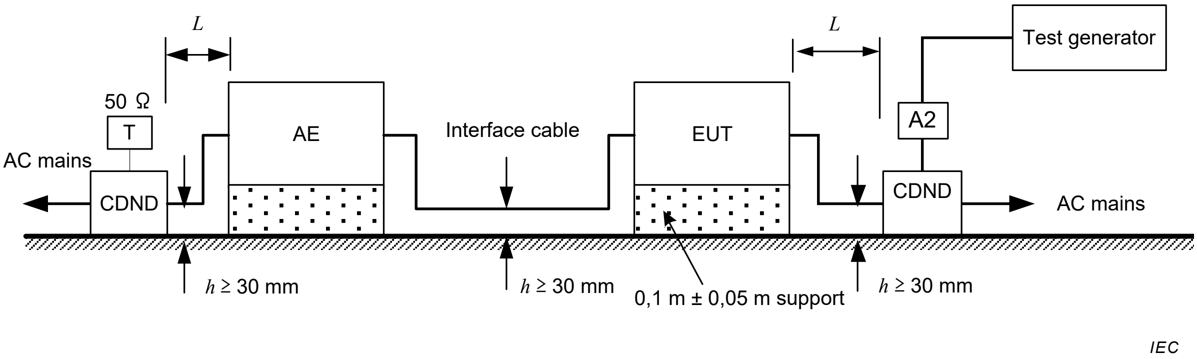
Figure 13 – Example of a test set-up for an EUT comprised of several units (top view)

7.4 CDN and CDND termination application

Only one of the CDNs or CDNDs that are connected via cables to ports not under test shall be terminated with 50 Ω. All other cables connecting untested ports shall be decoupled using a CDN and/or decoupling devices (see IEC 61000-4-6).

The CDN or CDND to be terminated shall be chosen according to the following priority:

1) CDND used for connection to AC mains port (not under test);
2) CDN-M1 used for connection of the earth terminal;
3) CDN-S*n* (*n* = 1,2,3...): If the EUT has several CDN-S*n* ports, the port which is closest to the port selected for injection (shortest geometrical distance) shall be used;
4) CDN-M2 used for connection to DC mains port;
5) Other CDNs connected to the port which is the closest to the port selected for injection (shortest geometrical distance).
   - If the AE is directly connected to the EUT (e.g. no decoupling on the connection between them as shown in Figure 14a)), then it is to be placed on the insulating support (0,1 ± 0,05) m above the reference ground plane and grounded via a terminated CDN.
   - If the AE is connected to the EUT via a CDN, then its arrangement is not generally critical and it can be connected to the reference ground plane in accordance with the manufacturer's installation requirements.
   - If the EUT has only one port (i.e. one AC mains port), that port is connected to the CDND used for injection.
   - If the EUT has two ports and only one CDND can be connected to the EUT, the other port shall be connected to an AE that has one of its other ports connected to a CDND (AC mains port) or a CDN terminated with 50 Ω in accordance with the above-mentioned priority (see Figure 14a)). All other connections of the AE shall be decoupled. If an AE connected to the EUT shows an error during the test, a decoupling device (preferably a terminated EM clamp) should be connected between the EUT and the AE (see Figure 14b)).
   - If the EUT has more than two ports and only one CDND can be connected to the EUT, it shall be tested as described for two ports but all other EUT ports shall be decoupled. If an AE connected to the EUT shows an error during the test, a decoupling device (preferably a terminated EM clamp) should be connected between EUT and AE, as mentioned above.



The interface cable shall be 1 m long if possible.

Figure 14a) – Schematic set-up for a 2-port EUT connected to only one CDND

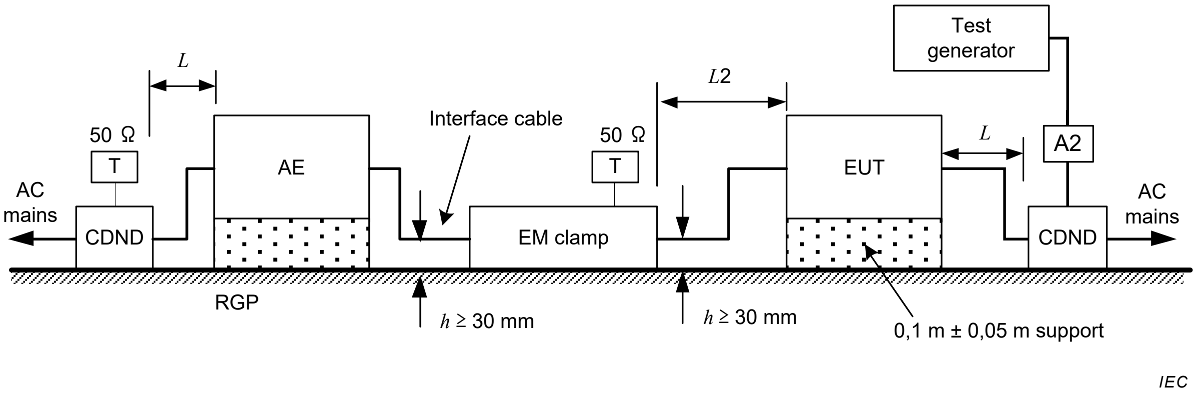


Figure 14b) – Schematic set-up when an AE shows errors during the test

Key

L	0,1 m ≤ *L* ≤ 0,3 m	*L*2	L2 ≤ 0,3 m
A2	optional power attenuator	T	termination 50 Ω

Figure 14 – Immunity test to a 2-port EUT (when only CDNDs can be used)

8 Test procedure

The testing shall be performed according to a test plan.

Attempts should be made to fully exercise the EUT during testing, and to fully interrogate all exercise modes selected for susceptibility.

Preliminary investigations on all testing aspects and the use of a special exercising program may be required.

The EUT shall be tested under its intended operating and climatic conditions.

Local interference regulations shall be adhered to with respect to the radiation from the test set-up. If the radiated energy exceeds the permitted level, a shielded enclosure shall be used.

NOTE Generally, this test can be performed without using a shielded enclosure. This is because the disturbance levels applied and the geometry of the set-ups are not likely to radiate a high amount of energy, especially at the lower frequencies.

The test shall be performed with the test generator providing the test signal to the RF input port of the CDND connected to the AC mains network. All other connected ports not under test shall be treated as described in 7.4.

An LPF and/or a HPF may be required at the output of the test generator to prevent (higher order or sub-) harmonics from disturbing the EUT. The band stop characteristics of the LPF shall be sufficient to suppress the harmonics so that they do not affect the results. These filters shall be in place with the test generator when setting the test level.

The broadband test signal shall be applied to the EUT according to the test level selected in the frequency range of interest and using the total forward power established by the test level setting procedure given in 6.4.2. The pulse modulation selected by the product committee is applied to the test signal during the dwell time. Pulse modulation is intended to simulate the keying behaviour of a disturbance signal. The dwell time for application of the broadband immunity test signal shall not be less than the time necessary for the EUT to be exercised and to respond and shall in no case be less than 60 s.

9 Evaluation of the test results

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test or by agreement between the manufacturer and the purchaser of the product. The recommended classification is as follows:

a) normal performance within limits specified by the manufacturer, requestor or purchaser;
b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;
c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;
d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which may be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- identification of the EUT and any associated equipment, for example brand name, product type, serial number;
- representative operating conditions of the EUT;
- whether the EUT is tested as a single or multiple unit;
- the types of interconnecting cables, including their length, and the interface port of the EUT to which they were connected;
- any specific conditions for use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance;
- the recovery time of the EUT if necessary;
- the type of test facility used and the position of the EUT, AE(s) and coupling and decoupling devices;
- identification of the test equipment, for example brand name, product type, serial number;
- the coupling and decoupling devices used on each cable;
- for each injection port, indicate which decoupling devices were terminated in 50 Ω;
- a description of the EUT exercising method;
- any specific conditions necessary to enable the test to be performed;
- the frequency range of application of the test;
- the rate of dwell time;
- the applied test level;
- the performance level defined by the manufacturer, requestor or purchaser;
- the performance criteria that have been applied;

- any effects on the EUT observed during or after application of the test disturbance and the duration for which these effects persist;
- the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser).

Annex A

(informative)

Measurement uncertainty of the power spectral density test level

A.1 General

Annex A gives information related to measurement uncertainty (MU) of the power spectral density generated by the test instrumentation according to the particular needs of the test method contained in the main body of the standard. Further information about MU can be found in [1, 2 and 3][1].

Annex A focuses on the uncertainties for level setting as an example and shows how an uncertainty budget can be prepared based both upon the measurement instrumentation uncertainty and the power spectral density test level setting procedure described in 6.4.

The subject of Annex A is the evaluation of MU of the injected power set in the case of 100 Ω EUT impedance, as required by the test level setting procedure in 6.4. The analysis of non-reproducibility issues, related to tests made by different laboratories on the same EUT are not in the scope of Annex A.

A.2 Uncertainty budgets for test methods

A.2.1 General symbols

The general symbols that appear in Table A.1 and listed below are a subset of those defined in [1].

X_i is the input quantity;

x_i is the estimate of X_i;

$u(x_i)$ is the standard uncertainty of x_i;

c_i is the sensitivity coefficient;

y is the result of a measurement, (the estimate of the measurand), corrected for all recognized significant systematic effects;

$u_c(y)$ is the (combined) standard uncertainty of y;

$U(y)$ is the expanded uncertainty of y;

k is the coverage factor.

A.2.2 Definition of the measurand

The measurand is the power spectral density SD as defined in Clause 5 and supplied to a 100 Ω load through the EUT port of the CDND.

A.2.3 MU contributors of the measurand

The following influence diagram in Figure A.1 gives examples of influence quantities upon the power spectral density test level. It should be understood that the diagram is not exhaustive. The most important contributors from the influence diagram have been selected for the uncertainty budget calculation example shown in Table A.1. At least these contributors listed in Table A.1 shall be used for the calculation of MU in order to obtain comparable budgets for

---

[1] Numbers in square brackets refer to the Bibliography.

different test sites or laboratories. It is noted that a laboratory may include additional contributors (for example, Type A) in the calculation of the MU, on the basis of its particular circumstances.

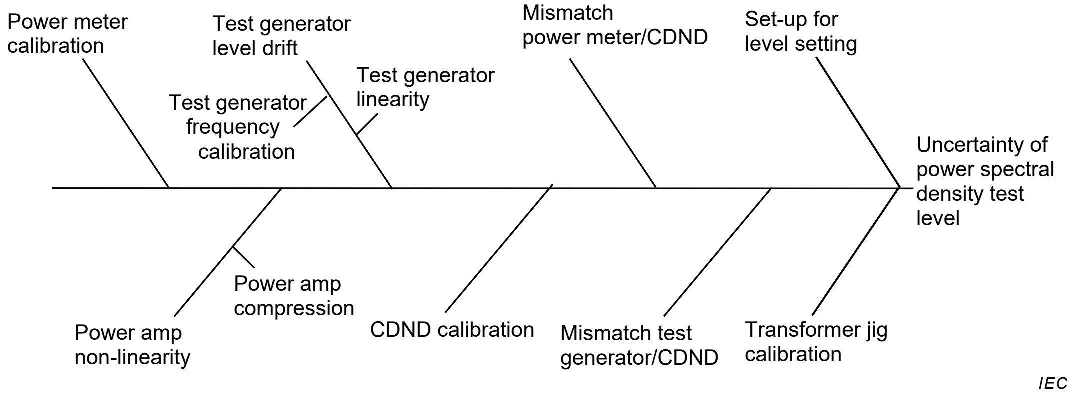


Figure A.1 – Example of influences upon the power spectral density test level using a CDND

A.2.4 Input quantities and calculation examples for expanded uncertainty

The examples below assume the same instrumentation used in the power spectral density level setting procedure is used for generating the power spectral density test level (the measurement set-up for the power spectral density level setting is that depicted in Figure 11), except for the measuring instrument (thermocouple power meter plus transformer jig), which is absent during the test.

Therefore the level of the power spectral density generated during the test will be affected by the same uncertainty that affects the power spectral density generated in the level setting process. The contribution to measurement uncertainty due to non-repeatability (e.g. caused by drift of the measuring instrumentation) is taken into account.

Table A.1 gives an example of an uncertainty budget for power spectral density level setting.

The model function for the CDND power spectral density SD generated in the level setting pro cess (all quantities in logarithmic units) is:

$$SD = PM_{\mathrm{r}} - IL - \Delta B + PM_{\mathrm{cal}} + FL_{\mathrm{G}} + FL_{\mathrm{C}} + R$$

where

SD	is the power spectral density (measurand);
PM_{r}	is the power meter reading;
IL	is the insertion loss of the transformer jig (6.3.3);
ΔB	is the test frequency band;
PM_{cal}	is the correction for power meter calibration;
FL_{G}	is the correction for flatness of the test generator (6.3.2);
FL_{C}	is the correction for flatness of the test instrumentation chain between the test generator output port and the EUT port of the CDND (6.3.4);
R	is the correction for repeatability.

Table A.1 – CDND level setting process

x_i	Description	Limit of error	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
PM_r	Power meter reading	0,1	dB	rectangular	1,73	0,06	dB	1	0,06	dB	0,00
IL	Insertion loss of the transformer jig	0,5	dB	normal k=2	2	0,25	dB	1	0,25	dB	0,06
ΔB	Test frequency band	0	dB	normal k=2	2	0,00	dB	1	0,00	dB	0,00
PM_{cal}	Power meter calibration	0,2	dB	normal k=2	2	0,10	dB	1	0,10	dB	0,01
FL_G	Flatness of the test generator	1	dB	rectangular	1,73	0,58	dB	1	0,58	dB	0,33
FL_C	Flatness of the test chain	2	dB	rectangular	1,73	1,16	dB	1	1,16	dB	1,34
R	Repeatability	0,5	dB	normal k=1	1	0,50	dB	1	0,50	dB	0,25
				$\Sigma u_i(y)^2$							2,00
				Combined uncertainty $u(y)= \sqrt{\Sigma u_i(y)^2}$							1,41
				Expanded Uncertainty $U = u(y) \times k$, $k = 2$							**2,83** **dB**

Explanation of symbols:

PM_r	It is the reading of the thermocouple power meter. The uncertainty of the reading is due to the resolution of the display and instability of the reading itself.
IL	It is the insertion loss of the transformer jig as measured according to the procedure described in clause 6.3.3. The measurement uncertainty of IL is originated from the inaccuracy of the network analyzer and from the common mode current circulating in the measurement set-up. Flatness of IL is accounted by the term FL_C (see below).
ΔB	It is the frequency band occupied by the test signal. The uncertainty of this term is originated from the frequency inaccuracy of the test generator.
PM_{cal}	It is the calibration factor of the power meter. Its uncertainty is reported in the calibration certificate of power meter. It is recommended that calibration uncertainty, non-linearity, and drift are taken into account when calculating the combined uncertainty of this term. It is assumed that the calibration factor remains essentially constant within the test frequency band. If calibration factor variation within the test frequency band cannot be neglected, the corresponding uncertainty contribution will be calculated and incorporated.
FL_G	It is the correction for the flatness of the test generator (see 6.3.2). Its expected value is 0 dB, and its upper and lower limits can be obtained from measurement or specification, if available.
FL_C	It is the correction for the flatness of the test instrumentation chain between the test generator output port and the EUT port of the CDND. Its expected value is 0 dB, and its upper and lower limits can be obtained from the insertion loss measurement described in 6.3.4.
R	It is the correction for non-repeatability of the measurement set-up and test instrumentation. Its expected value is 0 dB and its standard deviation is evaluated through several and independent repetitions of the level setting process. Repetitions should be conceived so that the main causes of non-repeatability are detected, such as environmental changes (temperature and humidity), cable connectors, drift of electronic instrumentation, different operators, and different layout.

A.3 Expression of the calculated measurement uncertainty and its application

MU is calculated in logarithmic units to make it homogeneous with the uncertainty contributions to power spectral density test level uncertainty (e.g. power meter amplitude specification and adapter insertion loss calibration) usually expressed in dB. Hence, the best estimate shall also be expressed in logarithmic units (e.g. dBm/Hz).

The power spectral density shall be reported in terms of the best estimate and its expanded uncertainty.

An example of the presentation of measurement uncertainty is given in the example below:

In logarithmic units:

$$SD = -49{,}3\ \text{dBm/Hz} \pm 2{,}8\ \text{dB}$$

This corresponds, in linear scale, to:

$$SD = 11{,}7\ \text{nW/Hz} + (32\ \%) - (48\ \%)$$

The calculated MU may be used for a variety of purposes, for example as indicated by product standards or for laboratory accreditation. It is not intended that the result of this calculation be used for adjusting the test level that is applied to EUTs during the test process.

Annex B
(informative)

Rationale for the selection of the preferred broadband source – Information on test signal generation

B.1 General

This standard defines a band-limited broadband signal as test signal. Band-limited broadband signals can be generated in different ways. In cases where the immunity to signals produced by switched-mode power supplies and similar appliances is evaluated, an impulsive signal may be adequate. For communication systems (e.g. powerline communication) as disturbance source, an orthogonal frequency-division multiplexing (OFDM) scheme seems to be more appropriate. In the frequency domain (without taking the phase angle into consideration), the signals look quite similar, but in the time domain they differ significantly. Annex B gives some guidance on the realization of band-limited broadband signals and explains why a (physical) random noise signal is selected as preferred signal. Furthermore, the material may be helpful in cases where specific EMC problems need to be evaluated on the basis of signals more representative of the real disturbance source.

B.2 Principles of band-limited broadband signal generation

B.2.1 General

The examples given here are not exhaustive, but explain the principles of broadband signal generation.

Three basic principles for band-limited broadband signal generation can be distinguished:

- use of a wide band signal generator and limitation of the frequency band by an attached bandpass filter (physical noise, pseudo noise);
- use of an impulse generator with an appropriate pulse shape;
- generation of a signal which intentionally contains only frequencies within a certain frequency band (OFDM scheme).

B.2.2 (True) random noise generation

True random noise generation makes use of a white noise source (e.g. shot noise in a semiconductor diode). For band limitation, a bandpass filter restricts the spectral content of the noise generator output to the required frequency band (see Figures B.1a) and B.1b)). The filter characteristics determine the created signal spectrum. High order filters need to be realized in order to fulfil the requirements for the slopes at the limiting frequency edges.

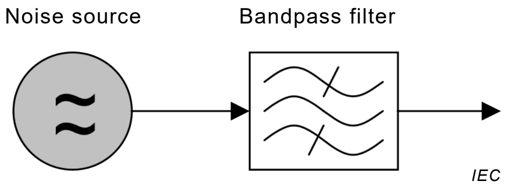
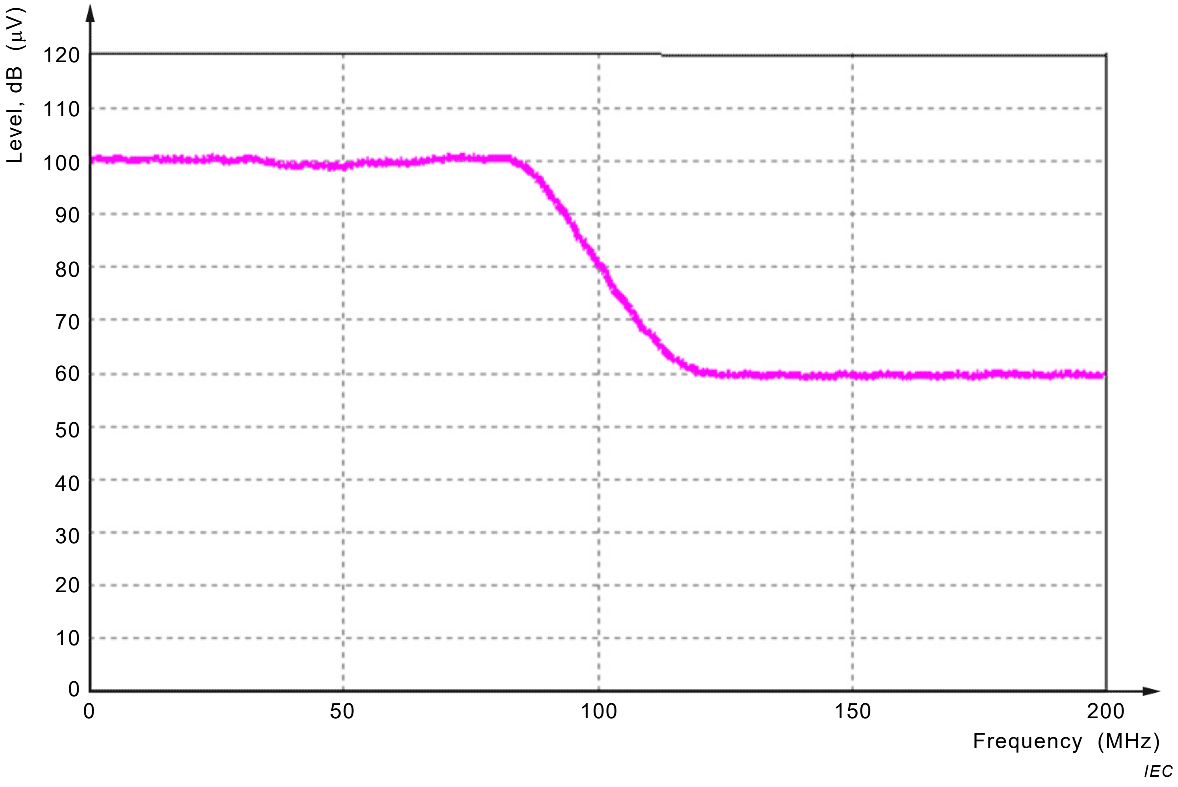


Figure B.1a) – Principle of true random noise generation



The bandwidth/filter characteristics depend on the requirements for the slopes given in the main body of this standard.

Figure B.1b) – Example of a band-limited random noise signal

Figure B.1 – White noise source

B.2.3 Pseudo-random noise sequence

The true random noise source can be replaced by a random number sequence uploaded into the memory of an arbitrary waveform generator (AWG). To allow an easier implementation of the band filter the sample sequence can be preconditioned. Thus, only an anti-alias filter is physically needed at the AWG output (see Figure B.2). The design of this filter is not as demanding as for the true random noise generation, when a sufficiently large sampling frequency of the AWG is selected. The edge frequency of the anti-alias filter is usually half of the sampling frequency.

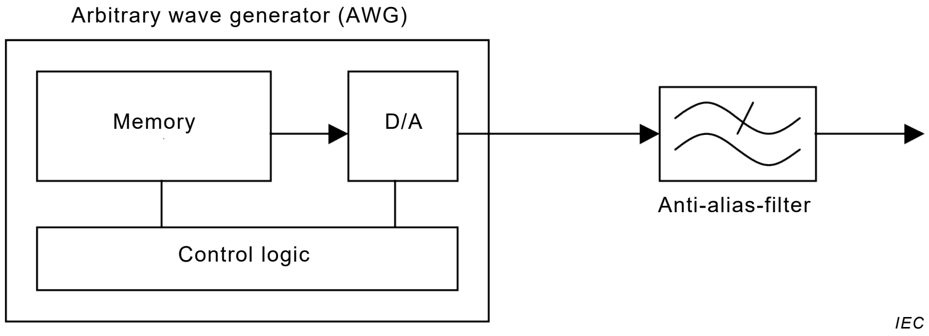


Figure B.2 – Principle of band-limited broadband signal generation with an arbitrary waveform generator

Let $s(t)$ be the sequence of random numbers. This signal is frequency independent (at least in a frequency interval up to half of the sampling frequency) and can be expressed in the frequency domain as $S(\omega)$. The filtering can be made in the frequency domain by multiplying $S(\omega)$ with a filter characteristic $H_\mathrm{F}(\omega)$. A rectangular function $H_\mathrm{n}(\omega)$ in the frequency domain:

$$H_n(\omega) = \begin{cases} 1 & \text{for} \quad |\omega| < \omega_n \\ 0 & \text{else} \end{cases} \tag{B.1}$$

corresponds to the function $h_\mathrm{n}(t)$ in the time domain:

$$h_n(t) = \frac{\omega_n}{\pi} \cdot \mathrm{sinc}(\omega_n \cdot t) \tag{B.2}$$

with:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}. \tag{B.3}$$

The filter for the wanted signal spectrum with the lower border frequency f_1 ($\rightarrow \omega_1 \rightarrow H_1(\omega)$) and the upper border frequency f_2 ($\rightarrow \omega_2 \rightarrow H_2(\omega)$) is:

$$H_F(\omega) = H_2(\omega) - H_1(\omega) \tag{B.4}$$

with the corresponding pulse response in time domain:

$$h_F(t) = \frac{\omega_2}{\pi} \mathrm{sinc}(\omega_2 \cdot t) - \frac{\omega_1}{\pi} \mathrm{sinc}(\omega_1 \cdot t) \tag{B.5}$$

The application of the filter to the random number sequence in the frequency domain corresponds to a multiplication. In the time domain, it becomes a convolution operation:

$$g(t) = h_F(t)\, s(t) \tag{B.6}$$

If this sequence $g(t)$ is loaded into the memory of an AWG, the corresponding spectrum is the spectrum defined in the main part of the standard.

Figure B.3 shows the spectrum measured with a measurement receiver (AV detector, 120 kHz resolution bandwidth, frequency step 50 kHz) for a signal generated with an AWG with the following parameters:

- sampling frequency 250 MS/s;
- sampling length 500 μs (125 000 points);
- 14-bit vertical resolution;
- 100 MHz analog bandwidth;
- lower band limit 150 kHz;
- upper band limit 80 MHz.

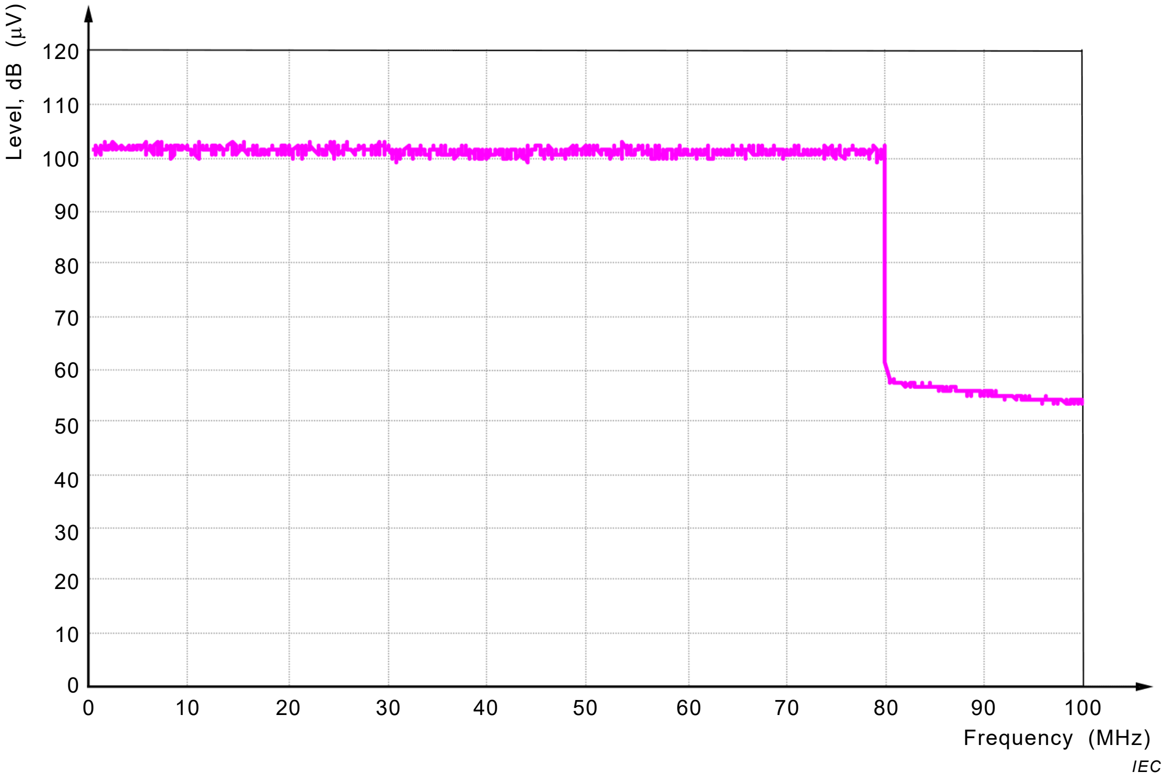


Figure B.3 – Signal spectrum of a band-limited pseudo-random noise signal (measured with a 120 kHz resolution bandwidth)

An extract of the output in the time domain is shown in Figure B.4.

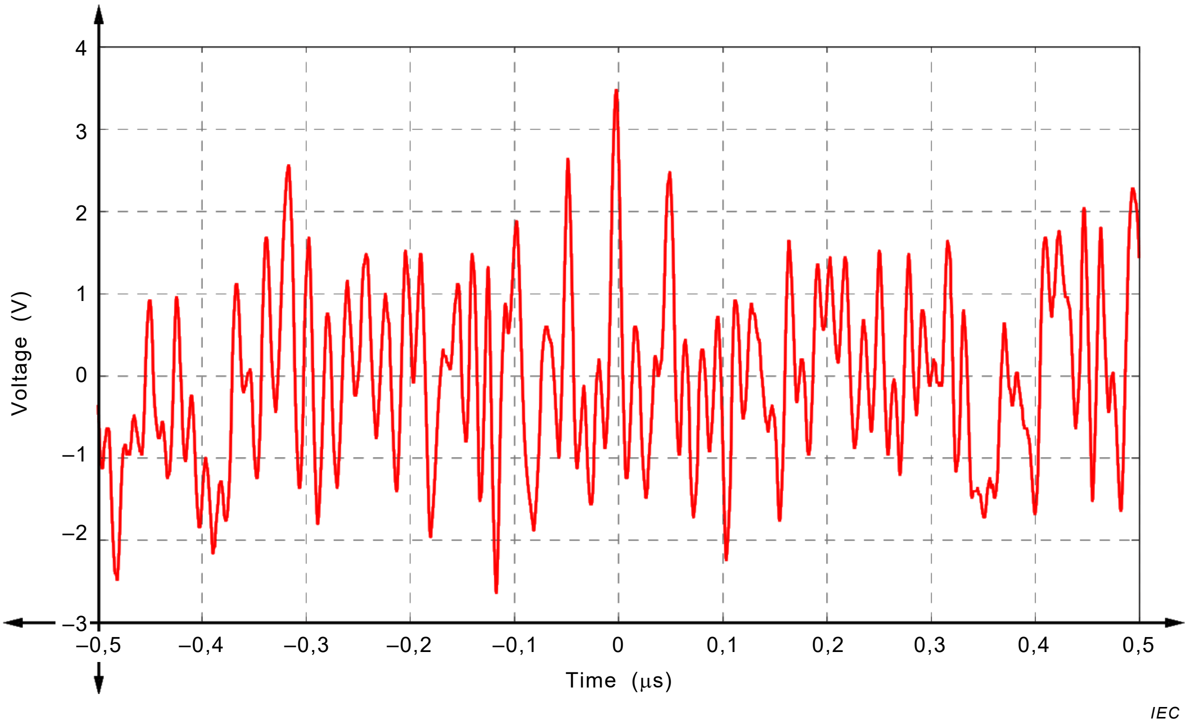


Figure B.4 – Extract of the band-limited pseudo noise signal in time domain (measured with an oscilloscope)

It has to be considered that some of the AWGs available on the market do not have a built-in anti-alias filter. In that case, mirror frequencies will show up at the higher frequency end of the spectrum (see Figure B.5). To avoid these spectral components, an external anti-alias filter needs to be applied.

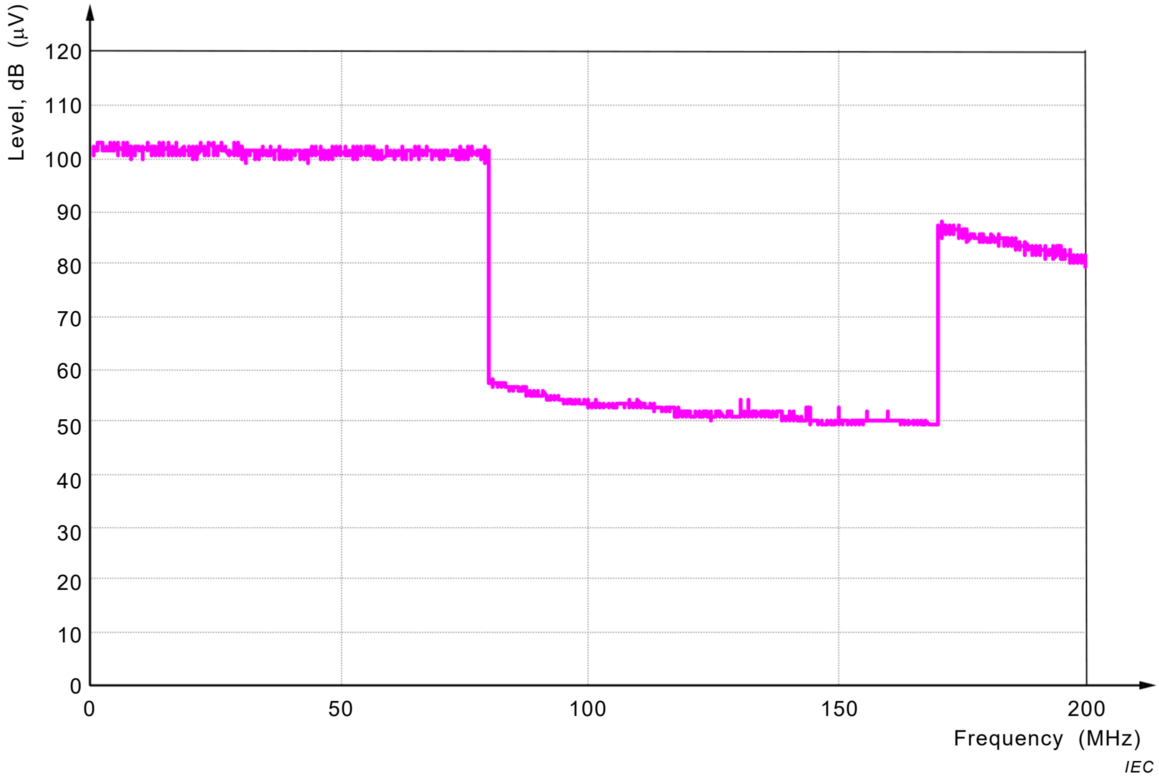


Figure B.5 – Signal spectrum of the band-limited pseudo noise signal without an anti-alias filter

There is another difference to the physically produced noise signal described in B.2.2. Since the length of the sampling sequence is finite, random periods should contain more than (2^{15}-1) samples, and the same sequence should be successively repeated by the generator in order to produce a continuous signal. Mathematically, this can be described by convolution of the sampling signal with a finite length and a comb signal. In the frequency domain, this means a multiplication between the signal spectrum obtained for the single sequence and a frequency comb, which yields a comb spectrum. The comb frequency corresponds to the length of the sequence. With a sequence length of 500 µs, a comb with a frequency spacing of 2 kHz will occur (see Figure B.6).

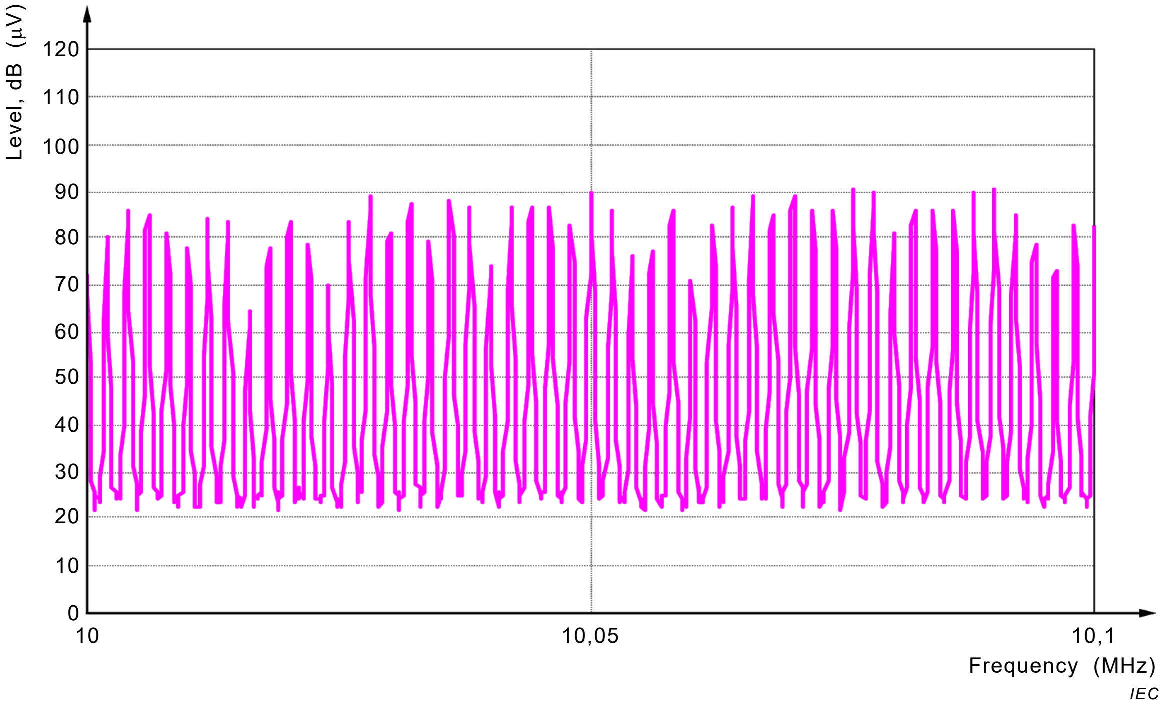


Figure B.6 – Extract of the signal spectrum of a band-limited pseudo noise signal (measured with a 200 Hz resolution bandwidth)

B.2.4 Impulse

Another way to produce a broadband signal is the direct use of the sinc-impulse (see Equation (B.5)). The spectrum obtained with the parameters:

- sampling frequency 250 MS/s,
- sampling length 200 µs (50 000 points),
- 14-bit vertical resolution,
- 100 MHz analog bandwidth,
- lower band limit 150 kHz, and
- upper band limit 80 MHz

can be seen in Figure B.7 (measured with a 120 kHz resolution bandwidth).

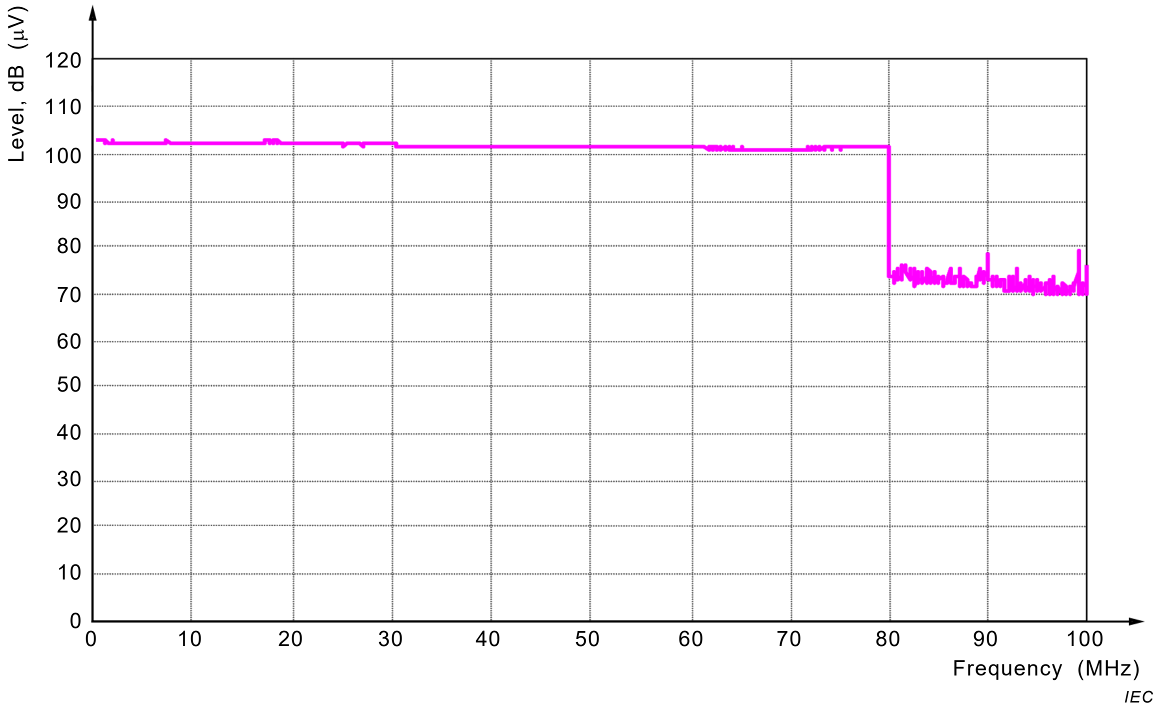


Figure B.7 – Signal spectrum of a band-limited impulse signal (measured with a 120 kHz resolution bandwidth)

Figure B.8 shows an extract in the time domain. This signal shows a poor crest factor, i.e. the relation between the peak amplitude and the average level. The amplifier shall be dimensioned to transmit the peak value without distortions.

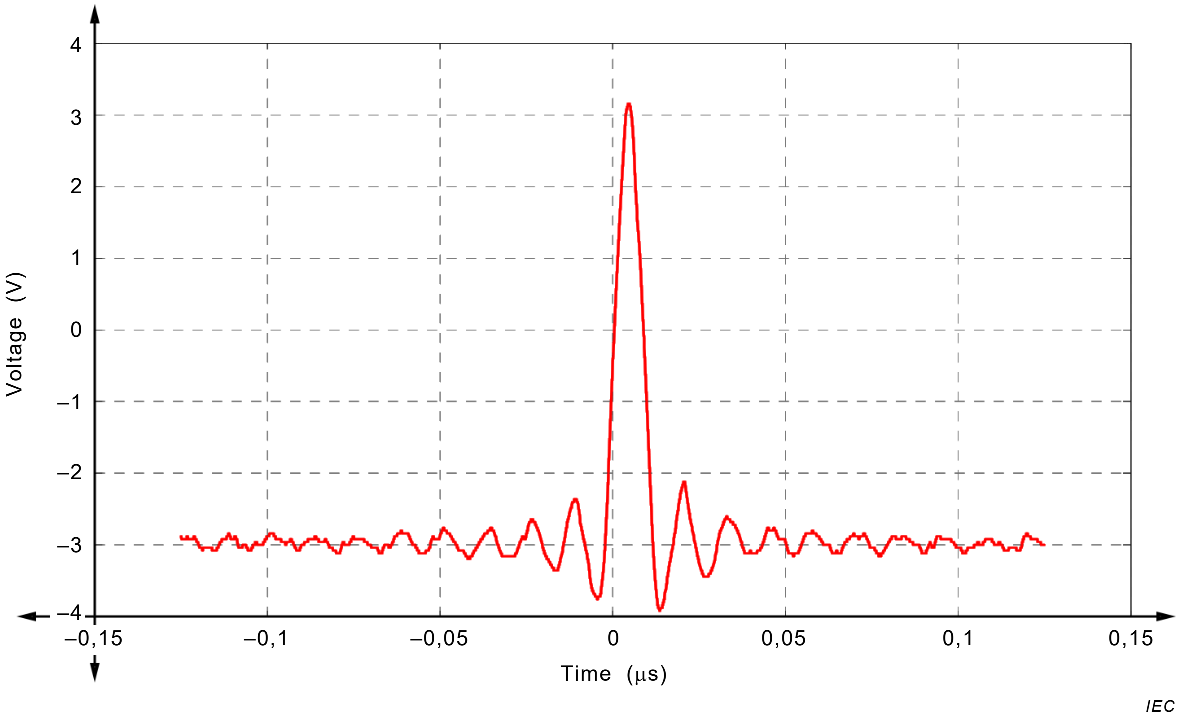


Figure B.8 – Extract of the band-limited impulse signal in time domain (measured with an oscilloscope)

Since the impulse is repeated in the time domain by the generator, a comb spectrum will be obtained, which can be seen in finer resolution (200 Hz resolution bandwidth) in Figure B.9.

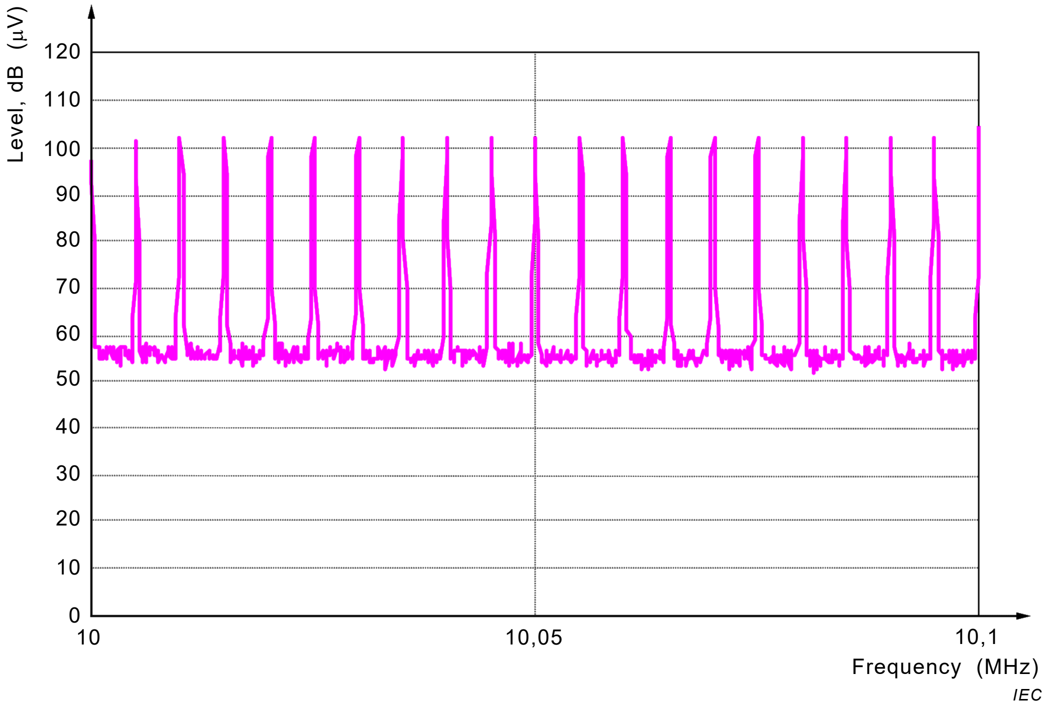


Figure B.9 – Extract of the signal spectrum of a band-limited impulse signal (measured with a 200 Hz resolution bandwidth)

B.2.5 OFDM scheme

The most sophisticated way to produce a broadband signal is to use an OFDM scheme as it is the basis for many modern communication systems.

A vector of complex random numbers (I, Q-values, symbol) is generated as payload.

The elements of the vector are modulated to a number of carriers separated by $1/T_{\text{symbol}}$, (with T_{symbol}: length of the symbol). Several symbols with random payload can be grouped together. Finally, the time sequence is loaded into the memory of the AWG. The output spectrum for a signal with the parameters:

- sampling rate 250 MS/s,
- symbol length 100 µs → carrier spacing: 10 kHz,
- frequency range 150 kHz to 80 MHz → 7 985 carrier,
- 5 symbols with random payload → sequence length 500 µs,
- 14-bit vertical resolution, and
- 100 MHz analogue bandwidth

is shown in Figure B.10. Since the generator repeats the sequence, a comb spectrum is produced again, which can be seen with finer resolution in Figure B.11.

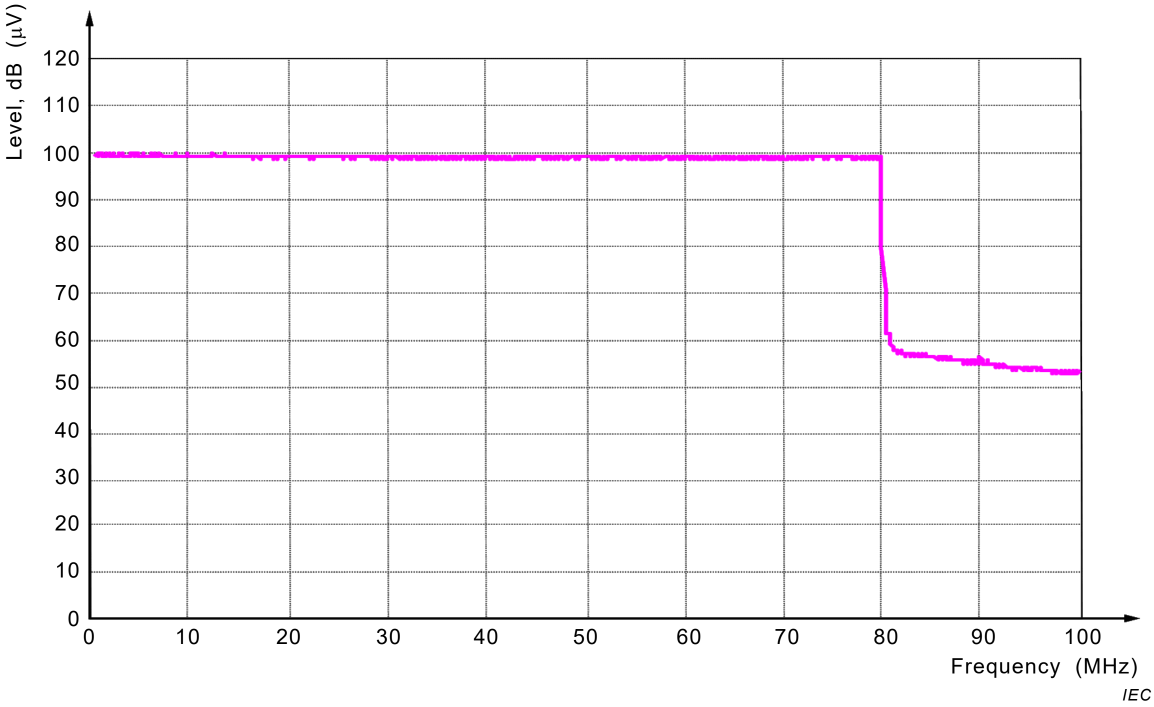


Figure B.10 – Signal spectrum of an OFDM signal (measured with a 120 kHz resolution bandwidth)

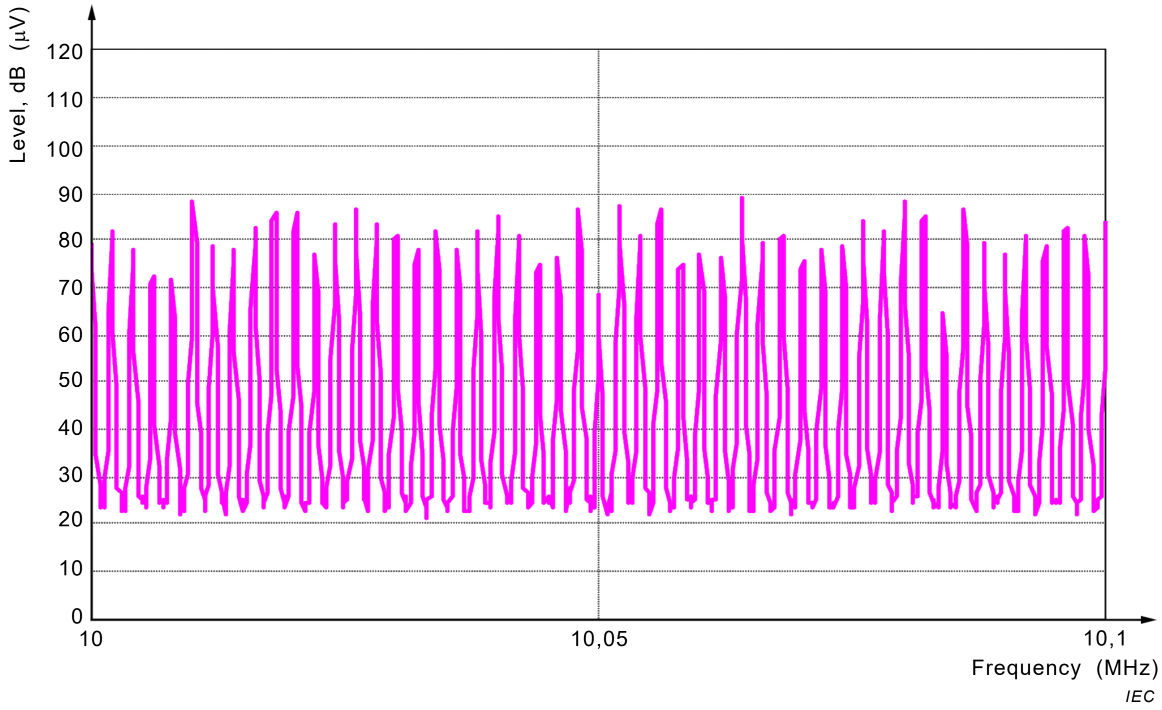


Figure B.11 – Extract of the signal spectrum of an OFDM signal (measured with a 200 Hz resolution bandwidth)

The mechanism to create the time sequence with the OFDM scheme allows the realization of arbitrary spectra. This allows for example the compensation of the frequency dependency of the power amplifier, cables and CDN. An example spectrum is shown in Figure B.12, where an amplitude step of 10 dB has been inserted at 30 MHz.

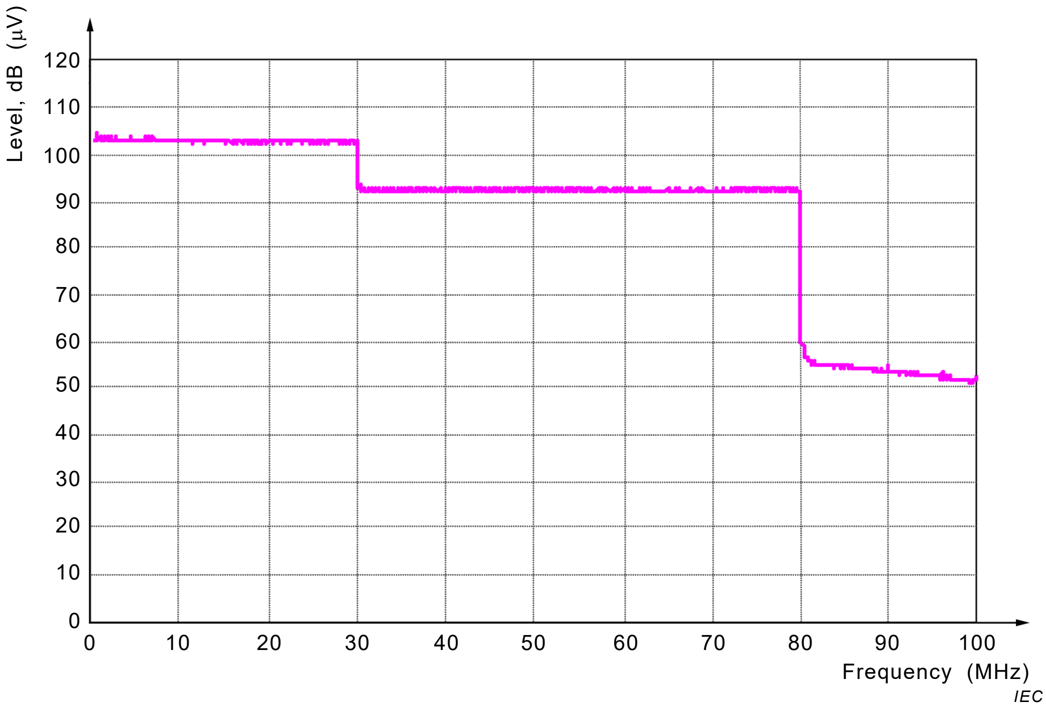


Figure B.12 – Signal spectrum of an OFDM signal with an amplitude step at 30 MHz (measured with a 120 kHz resolution bandwidth)

B.3 Selection of the preferred broadband source

There are several ways to produce a wideband test signal (see Table B.1). For the investigation of specific EMC problems, the use of a signal type representative of a disturbance source is appropriate. However, for a basic standard whose purpose is to simulate various types of disturbance sources, a disturbance signal representing a good compromise has to be defined.

Table B.1 – Comparison of white noise signal generation methods

Broadband signal type for testing	Example of disturbance sources			Complexity of test equipment
	Frequency converters Switched power supplies	PLT	Other communication systems (point2point)	
Noise	0	+ (if pulse modulated)	+	+
Impulse	++	–	–	– (amplifier)
OFDM	0	++	++	0 (definition of parameters required)

It seems that the band-limited noise source is the most suitable for a basic standard. Using OFDM would require to define the OFDM structure (number of carriers, constellation for the carriers, carrier spacing, etc.) to allow reproducible test results. The impulse signal is not adequately representing threats, such as PLT or other communication systems.

Bibliography

[1] IEC TR 61000-1-6, *Electromagnetic compatibility (EMC) – Part 1-6: General – Guide to the assessment of measurement uncertainty*

[2] UKAS, M3003, Edition 2, 2007, The Expression of Uncertainty and Confidence in Measurement, free download, www.ukas.com

[3] ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995)*

[4] CISPR 16-1-2, *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*

[5] ITU-T O.9:1999, *Measuring arrangements to assess the degree of unbalance about earth*

[6] ITU-R BT.1306-7:2015, *Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting*

[7] IEC GUIDE 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*

This page deliberately left blank

This page deliberately left blank

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
- The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
- A single paper copy may be printed for personal or internal company use only.

Standards purchased in hard copy format:

- A British Standard purchased in hard copy format is for personal or internal company use only.
- It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email subscriptions@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Useful Contacts

Customer Services
Tel: +44 345 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 345 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK